Education Research Highlights in Mathematics, Science and Technology 2018

Editors

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SECTION 1
MATHEMATICS EDUCATION

Classroom Assessment of Mathematical Modeling Tasks

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Introduction

Mathematical modeling and modeling in general has grown in popularity in school mathematics and other STEM areas (National Governors Association Center for Best Practices [NGA Center] & Council of Chief State Officers [CCSSO], 2010; Consortium for Mathematics and Its Applications [COMAP] & Society for Industrial and Applied Mathematics [SIAM], 2016). For instance, modeling has been included in assessments and documents such as the programme for international student assessment (PISA), national assessment of educational progress (NAEP), and guidelines for assessment in mathematical modeling education [GAIMME] report. Standards of education in mathematics and science place an increasing emphasis on modeling, where students are engaged in analytical thinking , reasoning, critical thinking, and problem solving skills (see National Council of Teachers of Mathematics [NCTM], 2014; Next Generation Science Standards [NGSS Lead State, 2013]; NGA Center & CCSSO, 2010). The growing awareness of the importance of modeling as an integral part of mathematical competencies for students requires thoughtful assessment of classroom mathematical modeling tasks.

The role of assessment in mathematical modeling is critical and complex. However, the use of modeling tasks in most classrooms is limited (Blum, 2015). One reason is that mathematical modeling is a challenging task that requires several competencies and skills including problem posing and problem solving. Additionally, mathematical modeling requires real-world knowledge from certain domains that may not be familiar to most teachers of mathematics in the classroom, and makes solutions less predictable and linear (Leong, 2012). Moreover, anecdotal experiences show that a common and frequent challenge that most teachers of mathematics face is the assessment of mathematical modeling tasks. According to the GAIMME report, mathematical modeling tasks do not always result in a simple, precise answer or the right solution and the literature on classroom assessment of modeling is scarce. Therefore, the question among most teachers of mathematics and even mathematics educators is how do we assess classroom mathematical modeling, and in particular, the modeling process?

To address this question, this article offers useful information with two purposes in mind. First, we emphasize the importance of formative and summative classroom assessments of mathematical modeling.

Second, we introduce an assessment framework developed by the authors with the potential to assist in assessing mathematical modeling tasks. We view assessment as an integral facet of teaching. According to the National Research Council (NRC, 2001), these are the three main purposes of assessment in student learning: a) to assist student learning (formative assessment), b) to measure individual achievement (summative assessment), and program evaluation. For the purpose of this article, we focus our attention on formative and summative assessments. Formative assessments support learning, whereas summative assessments measure achievement. Formative classroom assessments of mathematical modeling should be based on tasks that bring into focus modeling techniques, modeling strategies, and the steps in the modeling process that provide scaffolding for student learning of these aspects of modeling.

Formative assessment provides "information to be used as feedback to modify teaching and learning activities" (Black & Wiliam 1998, p. 104). Research related to teachers using formative assessments indicated changes in their assessment practices, which resulted in increases in student achievement (Black, Harrison, Lee, Marshall, & Wiliam, 2004). In this way, teachers and students can identify the level of students' progress and where development is still needed. An important type of summative classroom assessments are open-ended tasks that require modeling techniques, modeling strategies, and all of the steps in the modeling process; these can be graded using a holistic approach guided by a rubric. Therefore, this article provides a framework, the rationale for, and examples of these formative and summative assessment of mathematical modeling task.

A Brief History and Purpose of Mathematical Modeling

Emphasis on mathematical modeling in school mathematics has increased in the half century since Pollak noted that "many teachers of mathematics have never been involved in the process of building mathematical models of situations in the outside world" (Pollak, 1966, p. 122). Since 1980, COMAP has produced materials to help teachers teach mathematical modeling. For the past decade, PISA has encouraged the implementation of mathematical modeling worldwide (OECD, 2003), and the Moody Foundation and SIAM have promoted mathematical modeling through the Moody Mega Math (M3) challenge. Since 2010, the Common Core standards (NGA Center & CCSSO, 2010), have called for students to "apply the mathematics they know to solve problems arising in everyday life, society, and the workplace" (p. 7). Today there are instructional materials that incorporate mathematical modeling (e.g., COMAP, 2012, 2013); large-scale assessment of mathematical modeling (e.g., PISA, PARCC), and contests to assess mathematical modeling prowess (e.g., the M3 Challenge). More recently, COMAP and SIAM collaborated to develop guidelines for assessment and instruction in mathematical modeling education [GAIMME] report, (COMAP & SIAM, 2016), yet there is limited guidance to assist teachers of mathematics in assessing mathematical modeling.

To help bridge this gap, we focus on ways to help teachers to apply formative and summative assessment techniques to support learning and to measure performance on mathematical modeling tasks. According to the authors of the GAIMME report, mathematical modeling is "a process that uses mathematics to represent, analyze, make predictions or otherwise provide insight into real-world phenomena" (COMMAP & SAIM, 2016, p. 8). For us, mathematical modeling is a process that uses mathematics to represent, investigate, and reach conclusions about situations in the world around us. Such activities not only motivate students but also enrich their understanding of the underlying mathematics. The purposes of mathematical modeling include (a) supporting student interest in the learning of mathematics (Blum & Borromeo Ferri, 2009; Pollak, 2003), (b) making mathematics relevant and meaningful to students (English & Watters, 2004; Flavres & Schiff, 2013), (c) providing students the opportunities to improve their problem-solving skills and mathematical abilities (English, 2007; Lesh, 2012), and (d) improving student achievement in mathematics (Boaler, 2001; English, 2007).

Mathematical modeling as a process involves mathematization, interpretation, and communication. According to Pollak (2011), mathematical modeling is a process that teaches students how to use mathematics in everyday life and in intelligent citizenship. A crucial aspect of teaching mathematical modeling is to help students internalize the mathematical modeling process. Extending beyond traditional word problems, mathematical modeling focuses on the iterative nature of the modeling process and provides multiple point of entry (Blum, 2011). Modeling requires knowledge of contexts beyond the classroom that may not be familiar to students and teachers, and modeling problems have solution paths that are less straightforward and predictable than traditional word problems (Pollak, 2011; Zbiek & Conner, 2006).

The Assessment Triangle and Assessing Mathematical Modeling

In our approach to classroom assessments of mathematical modeling tasks, we employ the elements of the assessment triangle, which has three interactively linked elements: a cognitive model of the learning goal, a lens for observation (often a problem or task), and a scheme for interpreting the observed student work (NRC, 2001). Figure 1 illustrates the interconnectedness of these elements: cognition, observation, and interpretation. In a typical classroom, the teacher observes the work of students and interprets their understanding of the content being taught based on the amount and quality of that work. Often the underlying cognitive model is implicit or absent.

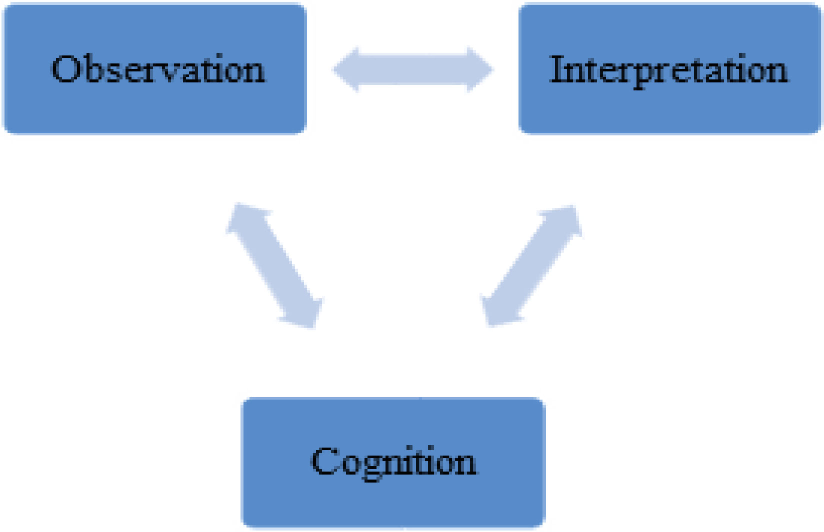

Figure 1. Assessment Triangle (adapted from the NRC 2001, p. 44)

In the assessment triangle model, cognition refers to the theory and set of beliefs about how students learn and represent knowledge to demonstrate competence. Below we present a schematic representation of mathematical modeling process to serve this purpose. Observation requires a description for assessments tasks that will elicit illuminating responses from students—the modeling tasks that allow the teacher to observe student learning (NRC, 2001). When assessing students modeling performance, the teacher monitors what the students say, do, and write. Interpretation encompasses all of the methods and tools used in reasoning about the task including assumptions, choices, and models developed. The interpretation shows the reasoning one makes from the student's evidence of learning. The assessment triangle model indicates that having all the three elements (cognition, observation, and interpretation) working together can provide an effective assessment framework. An explanation is that in the case of solving a modeling task, cognition will be clearly identifying the construct being learned and explicitly conceptualizing a cognitive model for the task. Next, and through observation, the modeler has to identify tools used to elicit the knowledge and skills associated with the construct being assessed. Then, the modeler has to make a decision based on the evidence from the observation tools through interpretation. All three are intertwined and provide a strong framework for assessing modeling tasks. According to Lyon (2011), the alignment between the elements can help identify whether teachers are assessing topics called for in STEM education reform efforts and if their tasks can actually provide evidence of student learning.

Assessment and Mathematical Modeling Performance

To have a clear knowledge as to how to assess mathematical modeling performance requires an understanding of the modeling process. In this section, we present a modeling process adopted from Blum and Leiss (2007) as a cognitive framework in assessing mathematical modeling performance. Because of the iterative nature of the modeling process, assessment of intermediate models and modeling process is crucial to progress toward an increasingly effective and efficient model (Zawojeski, 2016). The mathematical models students generate and the mathematics they bring to bear during the modeling process, provide a window into their mathematical ways of thinking (Diefes-Dux, Hjalmarson, & Zawojewski, 2013). According to Pollak (2003), the modeling process is where one identifies a situation in the real world, makes certain assumptions, and then uses a mathematical model to obtain a mathematical formulation to get results that can be translated back into the real world to validate the practicality of the results. Thus, the modeling process is a translation between the real world and mathematics in both directions.

The mathematical modeling process is a building link between mathematics as a way of making sense of our physical or social world and mathematics as a set of formal representations. The modeling process helps students comprehend mathematical concepts and teach them to formulate and solve specific situation-problems. Because mathematical modeling is an iterative process that involves elements of both a treated-as-real world and a mathematics world, several researchers have cited and used Blum and Leiss (2007) seven stages modeling process, while others have mentioned and used the CCSSM (NGA Center & CCSSO, 2010) six phase modeling cycle. There are three main reasons why the modeling process needs to be part of the teaching and assessing of mathematical modeling tasks: Modeling process a) offers students an understanding of what mathematical modeling means b) gives students orientation within their modeling process, and c) allows students to think about their modeling process and on a metacognitive level (Borromeo Ferri, 2018).

The slight variation in the modeling process is dependent on various directions and approaches of how mathematical modeling is understood and the task(s) employed. Zbiek and Conner (2006) explained that mathematical modeling is an iterative process involving revisions before one arrives at an acceptable conclusion and it involves movement among elements such as the real world situation, a mathematical entity, and a mathematical solution. We present a seven step modeling process or framework based on ideas from the two aforementioned modeling processes and Hall's (1984) modeling process. We did not explicitly use the modeling cycle described in the Common Core because the distinction between reality (the rest of the world) and mathematics was unclear as specified in other modeling processes. The unique feature of the modeling process presented in this article takes into account reality, the heuristic for teaching modeling, and the assessment framework for measuring mathematical modeling performance.

The modeling process depicted in Figure 2 describes and provides the necessary information used as the framework in assessing modeling performance. The cyclical nature of Figure 2 highlights the iterative nature of the modeling process. The phases in this modeling process include (a) understand the task, (b) setup a model, (c) devise the mathematical problem (mathematizing), (d) solve the mathematical problem, (e) interpret solution, (f) validate the model, and (g) report conclusions. Drawing on the modeling process, assessment of students modeling performance suggests two approaches: (a) holistic approach and (b) the different phases of the modeling process. Both methods of assessing modeling performance describe formative and summative forms of assessment. Additionally, targeting the phases in the modeling process warrants giving students feedback at all times whiles working on a modeling task, and this characterizes formative assessment of modeling performance.

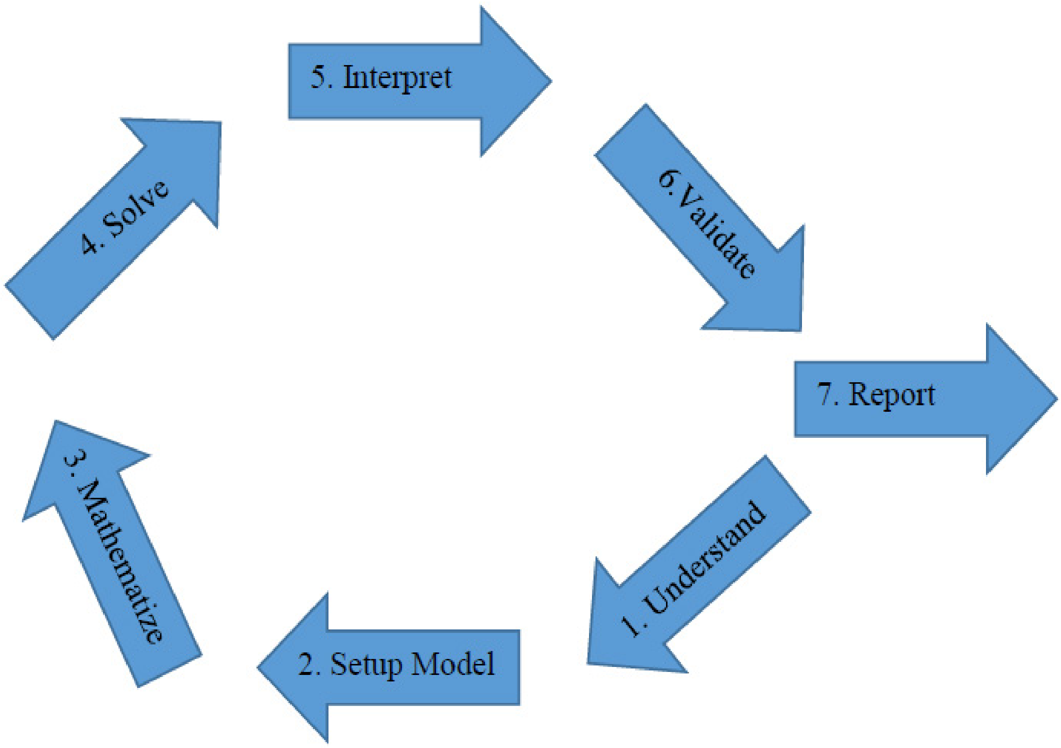

Figure 2. A Schematic Representation of Mathematical Modeling Process

Contextualizing the Modeling Process: The Hoodie Problem

To have an understanding of how the modeling process works, we discuss a specific modeling task in a context that most students will relate to in the hoodie problem as shown in Figure 3. A possible solution path is offered along with explanations that highlight the modeling process.

Hoodie Problem
You visit Egglawn University, and you wish to buy a hooded sweatshirt (hoodie) for your campus tour. An Egglawn hoodie costs $30 in shops uptown, near campus, and $35.00 downtown, near your residence. Is it worth going uptown to buy your hoodie?

Figure 3. Contextualizing Modeling: The Hoodie Problem.

Understand the Task. This phase requires the student to have some understanding about the task. Some knowledge and familiarity with cost, distance, and time functions will help in developing a model. At this phase in the modeling process, the following questions will help the problem solver: Do I know enough about the real situation? How do I model the situation? What is the purpose of the model? Additionally, the context of the task will generate some discussions to the solution process.

Setup a Model. At this phase in the process, the student need to consider which features of reality are to be included–making assumptions and choices—and choose a model that will serve the purpose in solving the problem. In this particular task, a good assumption will be the type of vehicle the student will be driving to go uptown. Other features for the student to consider might include the vehicle consumption, gas price, and distance between the two locations. Students can be guided at the meta-level to think about what information they need to determine which location will be a better buy and whether they have been provided with all the information.

Mathematize. Mathematizing the task at this phase in the modeling process is about the student deciding what to use–equations, graphs, symbols, technology, variables, diagrams, etc.–to move the problem into a mathematical world. Based on the assumptions mentioned in phase 2, one could create or come up with the following mathematical representations:

C: Downtown = \$35.00, C: cost of hoodie.

C: Uptown = \$30.00 + 2×d×c×g, d: distance, c: consumption, and g: gas price

C: Uptown < C: Downtown?

Solve the Mathematical Problem. At this phase, the student works mathematically to solve the mathematical model and problem based on the assumptions. One way to find a solution is to find the cost of buying the hoodie uptown. C: Uptown ≈ \$30.00 + \$2.17 = \$32.17. The mathematical results shows that C: Uptown < C: Downtown!

Interpret Solution. This phase is about interpreting outcomes. On the basis of the results, the student has to interpret the mathematical results in the real world situation. The student must check to ensure that the problem has been answered within the assumptions that have been made. Interpretations made require explicit assumptions and initial conditions. This will help students to understand that solutions to problems are limited by the context and are not easily transferable to other situations. Furthermore, does the mathematical model behave reasonably when conditions are changed? The student will discuss the results and will need to decide whether it is cheaper to buy the hoodie uptown or downtown.

Validate the Model. At this phase, the student has to discuss the strengths and weaknesses of the model and how it relates to the real world problem. The statement that "all models are wrong, but some are useful" is a reminder about oversimplification and ignoring underlying assumptions. The question that can be asked here could be: Is it worth it to drive about five miles to save \$2.83? Have we considered time, pollution, and risk involved to drive five miles? At this phase three things: evaluation, validation, and if possible iteration have to be considered. Evaluation addresses the situation whether the model fulfils its purpose. Validation focuses on comparing the conclusions with reality. Iteration comes into play when the mathematical model does not behave reasonably in comparison to the real world problem. In such a situation then the modeler (student) has to go back and check on the assumptions (phases 1 & 2). However, if the conclusions are acceptable, then the student moves to the final phase by reporting conclusions.

Report. This is the final phase and a valuable part in the modeling process where students use language and communication skills to express their mathematical ideas. It is at this phase that we can elicit and observe evidence of students' mathematical thinking. Reporting conclusions and the rationale behind them both in an oral and written form will help students develop communication skills needed for the 21st century. The report may include documentations of the students' progress through the phases of the modeling process and their final answers. Figure 4 illustrates a typical written report based on the hoodie problem.

One could go from downtown to uptown by car; distance (one way) is about 5 mi, consumption 1 gal/18 mile, and gas cost \$2.45/gal.

C: Downtown = \$35.00

C: Uptown = \$30.00 + 2d×c×g

C: Uptown ≈ \$30.00 + \$2.17 = \$32.17

C: Uptown < C: Downtown!

Result: It is cheaper to buy the hoodie uptown!

However, drive 10 miles to save \$2.83?? Time?? Risk, Air pollution??

No, that is not worth driving, so we buy the hoodie downtown.

Figure 4. A Sample Solution Path to the Hoodie Problem

Formative use of Summative Assessment in a Modeling Task

Much work has been done in developing ways in which summative assessment of mathematical modeling task are carried out in various ways (Wake, 2009). Although this has had little impact on the general assessment of modeling tasks, the framework and structures developed in this article may well provide structures to inform formative assessment of modeling tasks in classrooms. The main goal of designing formative assessment is to assist learning. Consequently, formative assessment of modeling often focus on individual steps or strategies within the modeling process. In formative assessment, scaffolding can be provided within different phases of the modeling process, which allows students to learn about and compare models to get used to making several iterations around the modeling cycle and comparing the results as a means of validation. The Children in Hot Cars problem (adapted from Galbraith & Holton, 2018) below is an example to illustrate formative assessment of a modeling task.

The mix of formative and summative assessment of modeling tasks help students to show progress in problem solving and critical thinking skills. Formatively assessing students on this task through questions such as "what did you do here?, why did you do that?, or explain why you chose this approach? and scaffolding help elicit student thinking on the task. The information gathered through formative assessment may guide selection of future tasks and provide collective data that can be complied to yield a summative grade for students. This Children in Hot Cars problem will be used as a context to illustrate how students as modelers engage in formative use of summative assessment in modeling tasks:

> *Suppose you are asked to investigate why small children are so much at risk in locked cars in hot weather conditions, how would you solve this problem*?

Because modeling provides an opportunity for students to document and evaluate a wide range of conceptual understandings that may otherwise be difficult to document, we argue that the assessment of modeling tasks need to be embedded in the modeling process, rather than considered as an independent process (Eames, Brady, & Lesh, 2016). Formative assessment occurs during teachers' observation and interpretation of student models, which has the potential of improving instruction. Additionally, teachers engage in summative assessment when they evaluate the final models for effectiveness and efficiency to meet the criteria and constraints of the real-world modeling task. The assessment of the task associated with the modeling process may include a) formulating situations mathematically, b) employing mathematical concepts, facts, procedures, and reasoning, and c) interpreting and evaluating mathematical outcomes. (Zawojeski, 2016). Below is a typical response to the task with a mix of formative and summative assessment techniques embedded in the modeling process.

Understand the Task: In this phase, the modeler describes the real-world problem with the goal of specifying the mathematical problem.

Setup a Model: Here, the modeler tries to formulate the mathematical model. The modeler must consider which features of reality are to be included–making assumptions and choices—and choose a model that will serve the purpose in solving the problem.

Mathematize: For this specific task, one can assume the rate of fluid loss from a body depends on (is proportional to) its surface area, SA. Also, the amount of fluid in a body depends on (is proportional to) its volume, V. So a critical factor to consider, is the surface area/volume ratio of the body. Suppose we use a unit cube (see Figure 5) to represent the body of a person:

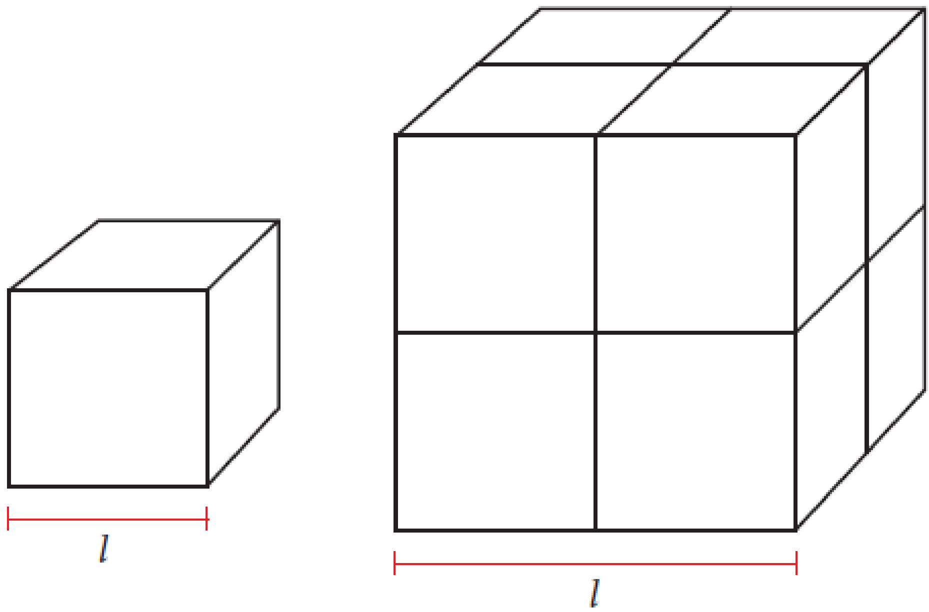

Figure 5. Sample Small and Large Cubes (adapted from Galbraith & Holton, 2018).

Then, SA of small cube = 6; V of small cube = 1; SA/V small cube = 6

SA of large cube = 24; V of large cube = 8; SA/V large cube = 3

Solve the Mathematics: Creating a table (see Table 1) of the ratio of blocks with lengths from 1 to 10, shows a pattern that smaller cubes have higher surface area/volume ratios than larger cubes. This indicates that smaller cubes have a greater surface through which to lose fluid relative to volume of fluid they have to lose. Thus, smaller cubes will lose fluid at a greater rate than larger cubes.

Table 1. A Table Showing Ratios of Block with Different Length Size.

Side Length of Cube	1	2	3	4	5	6	7	8	9	10
Ratio: SA/V	6	3	2	1.5	1.2	1	0.9	0.8	0.7	0.6

Interpret the Solution: Applying the mathematical understanding or logic from the previous modeling phase to the Children in Hot Cars problem suggests that children (smaller people) will have a higher surface area/volume ratio than adults (larger people). Therefore, children will lose more fluid quickly and they are at a higher risk of dehydration.

Validate the Model: Students can use geometric figures including cuboids, cylinders, or spheres to create physical models of children and adults to extend the simple unit cube approach to construct more elaborate representations to justify their conclusions. This provides students the opportunity to construct representations of people (children or adults) of their choice. Connected mathematical standards and practices will require students' knowledge on measurement and geometry.

Report: At this stage students can write a report in the form of a letter following the modeling framework structure to educate the public about the dangers of leaving children in hot cars.

Here, we described a task that was designed to engage students in mathematical modeling incorporating formative assessment approaches. During the iterations in the process of modeling, there are times at which formative assessment occurs—as students engage in mapping between the modeled world and real world, and when teachers support students in developing capability and facility with the iterative process of modeling (Eames, Brady, & Lesh, 2016). In this case, the task provides students the opportunity to create specific types of models, which they can compare, and draw conclusions. The tasks prompts student to make assumptions, explain their thinking, and provide rationale for their reasoning. A task like the Children in Hot Cars problem gives students opportunities to learn components of the mathematical modeling process that can then be applied to more open-ended summative and formative assessment tasks.

A Framework for Assessing Modeling Performance

The role of assessment in mathematical modeling is critical and complex. Because of the iterative nature of modeling, we believe formative assessment provides an effective and efficient approach in assessing modeling tasks. We present an assessment framework developed for assessing students' modeling performance that take into account the whole modeling process, phases in the modeling process, and the assessment triangle model. Because of the complex nature of mathematical modeling tasks, the assessment framework does not involve rubric scores but suggests two approaches in measuring students modeling performance. The approaches are (a) holistic approach, which involves technicality, originality and management, and presentation (Hall, 1984) and (b) the different phases of the modeling process.

These two methods reflect the elements of the assessment triangle model, and depict both formative and summative form of assessments. Moreover, teachers' minimal guidance, targeting areas that need work, and giving students feedback when working on a modeling task characterize formative assessment of modeling performance (Blum & Borromeo Ferri, 2009). The assessment framework helps teachers evaluate students' modeling performance and promotes familiarity with the elements in the modeling process to both teachers and students. Table 2 provides an explicit description of the assessment framework, which connects to each of the phases in the modeling process and elements in the assessment triangle model.

Table 2. A Framework for Assessing Mathematical Modeling Performance

A Framework for Evaluating Students' Mathematical Modeling Performance		
Categories	**Phase(s)**	**Element(s) Under Assessment Triangle**
Technicality		
Make sense of the task	1	Observation
Create realistic and applicable assumptions	2	Interpretation
Generate the appropriate mathematical model based on assumptions or choices	2 and 3	Interpretation and Cognition
Ability to manipulate the mathematical model to achieve desired results	3 and 4	Cognition
Originality & Management		
Capability to identify situation and formulate problem	1 and 3	Observation and Cognition
Ability to use other techniques or resources including technology	1 and 4	Observation and Cognition
Knowledge of when to change a model, method, or purpose when discussing the problem	6	Interpretation
Ability to recognize what constitute a solution to the real world problem	5 and 6	Interpretation
Ability to work effectively in a group	1–7	Observation, Interpretation, and Cognition
Presentation		
Ability to represent and interpret solution	7	Interpretation
Ability to translate and reflect upon the information	7	Interpretation
Ability to communicate evidently, especially both verbally and in writing	7	Interpretation

Implications and Conclusion

Assessment of mathematical modeling is an emerging area of research, theory, and practice that requires more study with the implementation of the Common Core standards for mathematics and the GAIMME report. Developing additional tools and ideas to measure mathematical modeling performance is timely and necessary. We hope that the ideas presented here will move this work forward. We recommend that other tools or rubrics to assess mathematical modeling be considered and employed depending on the purpose of the assessment (e.g., Anhalt & Cortez 2015; Hall, 1984; Leong, 2012; Munakata, 2006).

When teachers actively engage in formative assessment of modeling tasks during their observation, their interpretations of student models can inform ways to improve instruction, implements strategies, and even revise course content (Diefes-Dux, Hjalmarson, & Zawojewski, 2013). The assessment framework presented here suggests that it is beneficial to assess student mathematical modeling performance not only holistically (summative assessment), but also using task to focus on the phases of the modeling process giving students feedback (formative assessment). We hope that teachers, students, and researchers benefit from the framework presented. With this framework, we hope to advance the classroom assessment of mathematical modeling tasks.

References

Anhalt, C. O., & Cortez, R. (2015). Mathematical modeling: A structured process. *Mathematics Teacher 108*, 446–452.

Black, P., Harrison, C., Lee, C., Marshall, B., & Wiliam, D. (2004). Working inside the black box: Assessment for learning in the classroom. *Phi Delta Kappan 86*(1), 9–21.

Black, P., & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan 80*(2), 139–148.

Blum, W. (2015). Quality teaching of mathematical modelling: What do we know, what can we do? In S. J. Cho (Ed.), *Proceedings of the 12th International Congress on Mathematical Education: Intellectual and attitudinal challenges* (pp. 73–96). New York, NY: Springer.

Blum, W. (2011). Can modeling be taught and learnt? In B. Kaiser (Ed.), *Trends in teaching and learning of mathematical modeling: International perspectives on the teaching and learning of mathematical modeling* (pp. 15–30). New York, NY: Springer.

Blum, W., & Leiss, D. (2007). How do Students and teachers deal with modelling problems? In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds), *Mathematical modelling: Education, engineering and economics–ICTMA 12*, (pp. 222–231). Chichester, United Kingdom: Ellis Horwood.

Blum, W., & Borromeo Ferri, R. (2009). Mathematical modelling: Can it be taught and learnt? *Journal of Mathematical Modelling and Application 1*(1), 45–58.

Boaler, J. (2001). Mathematical modelling and new theories of learning. *Teaching Mathematics & Its Applications 20*(3), 121–27.

Borromeo Ferri, R. (2018). *Learning how to teach mathematical modeling in school and teacher education*. Picassoplatz, Switzerland: Springer.

Consortium for Mathematics and Its Applications (2012). *Modeling with mathematics: A fourth year course* (2nd ed.). New York, NY: W. H. Freeman.

Consortium for Mathematics and Its Applications (2013). *Mathematics: Modeling our world*. *Course 1*. New York, NY: W. H. Freeman.

Consortium for Mathematics and Its Applications [COMAP] and Society for Industrial and Applied Mathematics [SIAM] (2016). *Guidelines for assessment and instruction in mathematical modeling education*. Retrieved from http://www.siam.org/reports/gaimme.php

Diefes-Dux, H. A., Hjalmarson, M. A., & Zawojewski, J. S. (2013), Student team solutions to an open-ended mathematical modeling problem: Gaining insights for educational improvement. *Journal for Engineering Education*, *102*(1), 179–216.

Eames, C.L., Brady, C., & Lesh, R. (2016). Formative self-assessment: A critical component of mathematical modeling. In C. R. Hirsch (Ed.), *Mathematical modeling and modeling mathematics* (pp. 229–237). Reston, VA: National Council of Teachers of Mathematics.

English, L. D. (2007). Interdisciplinary modelling in the primary mathematics curriculum. In J. Watson & K. Beswick (Eds.), *Proceedings of the 30th Mathematics Education Research Group of Australasia Annual Conference* (pp. 275–284). Hobart, Australia: Mathematics Education Research Group of Australia.

English, L. D., & Watters, J. J. (2004). Mathematical modelling with young children. In J. M. Hoines, & A. B. Fuglestad (Eds), *Proceedings of the 28th International PME Conference*, (pp. 335–342). Bergen, Norway: Bergen University College.

Flevares, L. M., & Schiff, J. R. (2013). Engaging young learners in integration through mathematical modeling: Asking big questions, finding answers, and doing big thinking. *Advances in Early Education and Day Care*, *17*, 33–56.

Galbraith, P., & Holton, D. (2018). *Mathematical modelling: A guidebook for teachers and teams*. Retrieved from.https://www.immchallenge.org.au/files/IM2C-Teacher-and-student-guide-to-mathematical-modelling.pdf

Hall, G. (1984). The assessment of modelling projects. In J. S. Berry, D. N. Burghes, I. D. Huntley, D. J. G. James, & A. O. Moscardini (Eds.), *Teaching and applying mathematical modelling* (pp. 143–148). Chichester, United Kingdom: Horwood.

Lesh, R. (2012). Research on models & modeling and implications for common core state curriculum standards. In R. L. Mayes & L. L. Hatfield (Eds.), *WISDOM [e] monograph: Quantitative reasoning and mathematical modeling: A driver for STEM integrated education and teaching in context* (Vol. 2, pp. 197–203). Laramie, WY: University of Wyoming.

Leong, R. K. E. (2012). Assessment of mathematical modeling. *Journal of Mathematics Education at Teachers College*, *3*, 61–65.

Lyon, E. G. (2011). Beliefs, practices, and reflection: Exploring a science teacher's classroom assessment through the assessment triangle model. *Journal of Science Teacher Education 22*(5), 417–435.

Munakata, M. (2006). A little competition goes a long way: Holding a mathematical modeling contest in your classroom. *Mathematics Teacher*, *100*, 30–39

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics.* Washington, DC: Author. Retrieved from http://corestandards.org/assets/ CCSSI_Math%20 Standards.pdf

National Research Council. (2001). *Knowing what students know*: *The science and design of educational assessment.* Washington, DC: National Academy Press.

Organisation for Economic Co-operation and Development (2003). *The PISA 2003 assessment framework—mathematics, reading, science and problem solving, knowledge, and skills.* Paris, France: OECD Press.

Pollak, H. O. (1966). On individual exploration in mathematics education. In E. G. Begle (Ed), *The role of axiomatics and problem solving in mathematics* (pp. 117–122). Washington, DC: Conference Board of the Mathematical Sciences.

Pollak, H. O. (2003). A history of the teaching of modelling. In G. Stanic & J. Kilpatrick (Eds.), *A history of school mathematics* (Vol. 1, pp. 647–671). Reston, VA: National Council of Teachers of Mathematics.

Pollak, H. O. (2011). What is mathematical modeling? *Journal of Mathematics Education at Teachers College, 2*, 64.

Wake, G. (2009). Modelling and formative assessment pedagogies mediating change in actions of teachers and learners in mathematics classrooms. Retrieved from http://ife.ens-lyon.fr/publications/edition-electronique/cerme6/wg11.pdf

Zawojewski, J.S. (2016). Assessing mathematical modeling. In C. R. Hirsch (Ed.), *Mathematical modeling and modeling mathematics* (pp. 227–228). Reston, VA: National Council of Teachers of Mathematics.

Zbiek, R., & Conner, A. (2006). Beyond motivation: Exploring mathematical modeling as a context for deepening students' understandings of curricular mathematics. *Educational Studies in Mathematics, 63,* 89–112.

Models of the Mathematical Curriculum for the VI Middle School Grade Developed in B&H, Croatia, Montenegro and Serbia

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Introduction

The term 'Mathematics Curriculum' refers to the lessons and academic content taught in a school in a specific grade. In dictionaries, curriculum is often defined as the courses offered by a school, but it is rarely used in such a general sense in schools. Depending on how broadly educators define or employ the term, curriculum typically refers to the knowledge and skills students are expected to learn, which proficiencies educated student will develop (Kilpatrick, Swafford and Findell, 2001). It includes the learning standards or learning objectives they are expected to meet (Bloom, 1956; Krathwohl, Bloom and Masia, 1964). In addition, it conclude the units and lessons that teachers teach; the assignments and projects given to students; the books, materials, videos, presentations, and readings used in a course; and the tests, assessments, and other methods used to evaluate student learning. Since a mathematics curriculum of any Middle school grade is one of the foundational elements of effective schooling and mathematics teaching, it is often the object of reforms, most of which are broadly intended to either mandate or encourage greater curricular standardization and consistency across states, schools, grade levels, included subject areas, and so on...

Teachers typically modify what they teach and bring their curriculum into "alignment" with the learning expectations outlined in the standard, in the case of a socio-political community adopting new learning standards in mathematics at state, district or school levels. While the technical alignment of the curriculum with the standards does not necessarily mean that teachers are teaching in accordance with the standards - or, more to the point, that students actually achieve those learning expectations-the standards of learning remain a mechanism by which policy makers and school managements attempt to improve curriculum and teaching quality. The 'Common Core of National Standards for Mathematics', if it existed, for example, could be interpreted as a national and academic effort to influence curriculum design and teaching quality in schools through the adoption of new learning standards by the Ministry of Education.

Another reform strategy that indirectly influences curriculum is assessment, since the methods used to measure student learning compel teachers to teach the content and skills that will eventually be evaluated. The most commonly discussed examples are standardized testing and high-stakes testing, which can give rise to a phenomenon informally called "teaching for the test."

Schools may try to improve curriculum quality by bringing teaching activities and course expectations into "alignment" with learning standards and other school courses - a practice sometimes called "curriculum mapping." The basic idea is to create a more consistent and coherent academic program by ensuring that teachers teach the most important content and eliminate learning gap that may exist between sequential courses and grade levels. For example, teachers may review their mathematics program to ensure that students are actually be educated in every arithmetical part (when students are expected to develop arithmetic and early-algebraic thoughts) or geometrical parts (when students are expected to understand and accept the planned elements of geometry at 'Level 0' and 'Level 1' according to the van Hiele classification (Van Hiele, 1986)), offered in the school, not only reflects the expected learning standards for that, but also that it also prepares students for algebraic and geometrical parts in V - VIII grades (when elements of algebraic thinking are expected to develop in cognitive levels of educated students, and when students should understand and accept geometric concepts and processes with them at 'level 1' and within 'level 2').

The design and goals of any mathematics curriculum reflect the educational philosophy-whether intentionally or unintentionally-of the curriculum designers who developed it. Consequently, the curriculum reform may occur through the adoption of a different philosophy or model of teaching by a school or educator. Schools that follow the 'The traditional approach' or 'Model of Didactic situations' (Brousseau, 2002; Sierpinska, 2003) or 'Theory of Realistic Mathematics Education' (Freudenthal, 1991; Gravemeijer, 1994), for example, embrace a variety of approaches to teaching generally known as project-modeling based learning, which encompasses related strategies such as community-based learning and authentic learning. Also, under the philosophy incorporated into the curriculum, we mean the orientation of a legislator of a socio-political community and curriculum designers to accept and encourage a differentiated approach to teaching and students' learning.

In the school systems of socio-political communities whose mathematical education we observe, they have a centralized system of curriculum design by their ministry of education. At the beginning of his career, a teacher of mathematics asks himself, 'What should a mathematical curriculum contain?' Such a teacher needs of any kind of help that would enable him to organize his teaching more efficiently and that the results of his work would be to reach the goals of the teaching of mathematics in a high percentage.

He needs not only the goals of teaching mathematics and planned outcomes, but also much more important instruction with many details on how to achieve these goals and what teaching tasks to accomplish with the intention to achieve these goals. In addition, he needs the detailed instruction which teaching tasks he should be realized in order to achieve the affective goals (Grootenboer, Lomas and Ingram, 2008) of the teaching planned for the appropriate level in the teaching process. Then, he needs instructions on how to meet expectations of the social and academic communities in the teaching process and with which success he has achieved them. For example, when it comes to socio-mathematical norms, he needs clear instructions how to check that students have adopted some of these planned norms. Also, if in a mathematics curriculum for a Middle School grade there is the orientation 'teacher must develop the students' ability of logical thinking', the teacher needs detailed instructions on which elements of logical thinking this applies. Has the designer of the curriculum used the slogan 'logical thinking' in rhetorical and colloquial sense, or was he thinking of some specific logical tautologies and rules of concluding?

The topic of this research is of general interest in the international community of researchers in mathematics education (Robitalle and Dirks, 1982; Hawson, 1983; MEPRC, 2003; Anderson, 2009; Yee, 2010; Gürlen, 2015; Seah et al, 2016; Hayes, 2017). Over the past twenty years, this academic community has shown a growing interest in comparative studies on mathematical curricula of various socio-political communities (For example, Seah et al, 2014; Hasić and Romano, 2018).

In this article, comparing the curricula of mathematics for the VI grade of Middle Scholl in B&B, Croatia, Montenegro and Serbia, we will estimate the characteristics of these models. This will apply to both 'teaching plans' and 'teaching programs' elements mentioned socio-political communities.

Comparison of the Curriculum models

Our intention with this text is to open a dialogue between the designers of mathematical syllabus. In the school systems of B&H, Croatia, Montenegro and Serbia, the term 'teaching plan' refers to the planned annual number of hours of mathematics. The term 'teaching program' refers to the objectives of teaching mathematics (general and individual), teaching contents, planned outcomes of mathematics and didactic instruction for teaching realizes. In B&H and Montenegro, the basic education system (Primary grades and Middle school's grades) lasts nine years. Therefore, the corresponding classes are: VII (B&H), VI (Croatia), VII (Montenegro) and VI (Serbia). Information on mathematics teaching plans for the observed grade in Middle schools in mentioned countries is presented in the following table:

Table 1. Teaching Plans of Mathematics for VI Grade

State	Number of Weekly Classes	Number of Annually Classes	FB&H = 1	Grades
B&H [FB&H]	4	140	1.000	II
B&H [RS]	4	144	1.029	VII
Croatia	4	140	1.000	VI
Montenegro	4	136	0.971	VII
Serbia	4	144	1.029	VI

The teaching contents of mathematics for the observed grade are the following

Table 2: Teaching Program of Mathematics for VI Grade

Thematic content	B&H		Croatia	Montenegro	Serbia
	RS	FB&H			
Fractions in decimal form					
Integers	+(25)				
			+	+(42)	+(24)
Rational numbers	+(45)				
		+(15)	+	+(41)	+(45)
Angle and Triangle					
		+(25)	+	+(23)	+(30)
Quadrilateral	+(22)				
		+(30)	+	+(20)	+(20)
The length of triangular line and	+				
		+(30)			
The length of quadrilateral line	+(18)				
		+(30)	+		
Areas of triangles and quadrilaterals	+				
					+(17)
Elemental combinatorial tasks					
				+(6)	

Legend: Numbers in brackets indicate the suggestions of the Ministry of Education about the necessary hours for teaching and learning of noted themes

[FB&H] In an official document from the Ministry of Education, Central Bosnia Canton, the goals of teaching mathematics are cumulatively for all grades of the Middle School. They are also classified into two categories: Goals of Course and Tasks of Course. The first cluster refers to the mathematical content of courses in all grades of the Middle School. The second cluster consists of nine statements of general character. Professionally speaking, an academic person well educated in the domain 'Didactic of Mathematics', none of the above statements can hardly classify them into one of the categories of teaching goals of mathematics according to Bloom's classification.

[RS] In the official document of the Ministry of Education of the Republic of Srpska, the objectives of teaching mathematics for the 7th grade of the Middle School are classified into two categories: General goals of teaching Mathematics and Specific goals of teaching mathematics. These are mostly rhetorical and plausible statements in general forms. In the second cluster, there are listed the planned outcomes of teaching mathematics in the 7th grade of the Middle School. Each mathematics teacher, familiar with Bloom's classification of teaching goals, finds it very difficult to recognize them as some of the Cognitive and / or More Effective Mathematics teaching goals

[MNE] The aims of teaching mathematics in the Montenegrin Middle School are realized through the realization and achievement of cognitive and process goals. Cognitive objectives include the knowledge that the student will acquire through the adoption of mathematical contents given in the programs. Process goals include skills and values that are evolving during and during the learning process. Although the term 'process goals' of teaching mathematics is not close to us, in order to illustrate of what is meant by such goals in the official document of the Institute for Education of Montenegro, we instance the following: Through the 'process goals' students should develop:

- Possibility of logical thinking, conclusion and generalization and mathematical proving;
- Quality and ability to formulate problems;
- Possibility of problem solving;
- The skills of interpreting the data shown in diagrams, tables or charts of different species;
- The use of geometric accessories and measuring instruments;
- Possibility to recognize situations in everyday life in which mathematical knowledge can be applied;
- Innovation and creative thinking;
- Possibility of critical thinking;
- Cultural, ethical, aesthetic and work habits, criteria and abilities.

[CRO] The goal of teaching mathematics is to acquire basic mathematical knowledge necessary for understanding phenomena and laws in nature and society. Also, the goal is to acquire basic mathematical literacy and the development of abilities and skills in solving mathematical problems.

[SRB] The goal of teaching mathematics in Elementary school is to ensure that all pupils acquire basic linguistic and mathematical literacy and advance to the realization of appropriate standards of educational achievement, and that:

- Enable students to solve problems and tasks in new and unknown situations;
- Enable students to express and explain their thinking and discuss with others;
- Develop motivation for learning and interest in the subject contents;
- Ensure that learners adopt the elementary mathematical knowledge required for understanding of phenomena and laws in nature and society;
- Enable students to apply mathematical knowledge in solving diverse tasks from life practice;

- Represents the basis for successful continuation of mathematics education and for self-education;

- Contributes to the development of mental abilities, forms a scientific view of the world and

- Comprehensive development of students' personality.

Our finding

Looking at the of mathematics curricula models for the VI year of the Middle School B & H, Croatia, Montenegro and Serbia, we are inclined to believe that there is general social orientation in the observed socio-political communities that the teaching and learning of mathematics is one of the key foundations of education. The explanation for social orientation for teaching Mathematics as a fundamental subject at the Middle School levels is presented below:

- Mathematics is a powerful means in a technology-oriented and information-rich society to help students acquire the ability to communicate, explore, conjecture reason logically and solve problems using a variety of methods.

- Mathematics provides a means to acquire, organize and apply information, and plays an important role in communicating ideas through pictorial, graphical, symbolic, descriptive and analytical representations. Therefore, mathematics at the middle school level helps to lay a strong foundation for both continuing education in secondary schools and students' lifelong learning, and provides a platform for the acquisition of new knowledge in this rapidly changing world. Therefore, mathematical experiences acquired at the Middle school level enable students to become mathematically literate citizens who are more able to cope with the demands of their future everyday life. The mastered mathematical proficiencies are tools to help students enhance their understanding of the world. They provide a foundation for the study of other disciplines in secondary and post-secondary education.

- Mathematics education is an intellectual endeavor through which students can develop their imagination, initiative, creativity and flexibility of mind, as well as their ability to appreciate the beauty of nature. Mathematics is a discipline which plays one of central roles in human culture. The development of mathematical thinking (arithmetic, early-algebraic, algebraic and geometric) in students greatly enhances their chances for better progress in future schooling and day-to-day challenges in forthcoming working responsibilities. We deeply believe that quality mathematical education and completely developed mathematical proficiencies, especially in. Affective domains, are allow students to become more moral persons and honest and better people.

The goals of the observed models of the mathematics curriculum, although not explicitly pointed out, have to develop in students:

(a) The ability to think critically and creatively, to conceptualize, inquire and reason mathematically, and to use mathematics to formulate and solve problems in everyday life, as well as in mathematical contexts and other disciplines;

(b) The ability to communicate with others and express their views clearly and logically in mathematical language;

(c) The ability to understand and manipulate numbers (capability to think arithmetically), symbols (capability to think algebraically) and other mathematical objects (capability to think geometrically);

(d) Number sense, symbol sense, geometric and spatial sense, measurement sense and capacity to appreciate structures and patterns;

(e) A positive attitude towards the learning of mathematics and an appreciation of the aesthetic nature and cultural aspects of mathematics.

Comments and Observations

A natural question posed by the authors of this research is the following: Are mathematics teachers the ones for whom such designed models of curriculum mathematics for the VI grade of Middle School are intended? Are these designed curricula enabled working teachers to construct with high standards their global and executive plans for the realization of their teaching? According to our deep conviction, before work, there is still a lot of work in the design, preparation and construction of executive plans for the implementation of these models. Curriculum models thus designed are much more relevant to school administration and supervisory services from Pedagogical Institutes than to implementers in the classroom. The problems encountered by the implementers of mathematics teaching in this Middle School class are the same as the problems that other teachers have. We do not know whether there are researchers in the observed socio-political communities whose field of interest is the development of mathematical curricula. The usual practice in these communities is that their Pedagogical Institutions form an ad hoc commission composed of teachers of mathematics who design curriculum models. It has been shown that such an approach is insufficient in quality and does not bring quality improvement.

References

Anderson, J. (2009). Mathematics curriculum development and the role of problem solving. *ACSA Conference 2009.*

Bloom, B. S. (1956).*Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive Domain Edition*. Longman, ISBN: 0-582-23010-9

Brousseau, G. (2002). *Theory of Didactical Situations in Mathematics*. Dordrecht: Kluwer Academic Publishers, ISBN: 0-792-34526-6

Hasić, A. and Romano, D. A. (2018). Comparative analysis of mathematics curricula for V grades in B & H, Croatia, Montenegro and Serbia Middle schools. *IMVI Open Mathematical Education Notes*. (Submitted)

Hawson, A. G. (1983). *Curriculum development and curriculum research: A historical and comparative view*. Berkshire : NFER-Nelson ISBN: 0-7005-0614-4.

Gravemeijer, J. P. E. (1994). *Developing Relistic mathematics Education*. Utrecht: CDbeta press.

Grootenboer, P., Lomas, G. and Ingram, N. (2008). The Affective domain and Mathematics education. In: H. Forgasz, A. Barkatsas, A. Bishop, B. Clarke, S. Keast, W-T. Seah, P. Sullivan and S. Willis (Eds.), *Research in Mathematics Education in Australasia 2004-2007* (pp. 255-270), Rotterdam: Sense Publishers.

Freudenthal, H. (1991). *Revisiting Mathematics Education*. *China Lectures*. Dordrecht: Kluwer Academic Publishers.

Gürlen, E. (2015). An analysis of mathematics curriculum at secondary level. *Procedia - Social and Behavioral Sciences 174* : 1404 – 1407.

Hayes, D. (2017). An analysis and evaluation of a mathematics curriculum leading to a proposal for an innovation to this curriculum. *The STeP Journal*, *4*(2): 79-89.

Kilpatrick, J., Swafford, J. and Findell, B. (2001) *Adding it Up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Krathwohl, D. R., Bloom, B. S. and Masia, B. B. (1964). *Taxonomy of Educational Objectives: The Classification of Educational Goals (Handbook II: Affective domain).* New York: David McKay Company.

MEPRC [Ministry of Education of People's Republic of China] (2003). *Mathematics Curriculum Standards*. University of Macau, China

Robitalle, D. and Dirks, M. (1982). Models for the Mathematics Curriculum. *For the Learning of Mathematics, 2*(3): 3-20.

W. T. Seah, W. T., Zhang, Q., Barkatsas, T., Law, H. Y. and Y.-C. Leu, Y.-C. (2014). Mathematics learning in mainland China, Hong Kong, and Taiwan: the values perspective. In C. Nicol, S. Oesterle, P. Liljedahl and D. Allan (Eds.). *Proceedings of the*

Joint Meeting of PME 38 and PME-NA 36, (vol. 5, pp. 145-152). Vancouver, BC: PME.

Seah, W. T., Andersson, A., Bishop, A. and Clarkson, P. (2016). What would the mathematics curriculum look like if values were the focus? *For the Learning of Mathematics,* 36 (1): 14-20.

Sierpinska, A. (2003). *Lecture notes on the Theory of Didactic Situations in mathematics*. Montreal: Concordia University

Van Hiele, P. M. (1986). *Structure and Insight. A theory of Mathematics Education*. Academic press Inc. ISBN: 0127141618

Yee, L. P. (2010). Designing a mathematics curriculum. *Indonesian Mathematical Society Journal on Mathematics Education.* 1(1): 1-10.

Adaptive Learning Systems in Mathematics Classrooms

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Introduction

Preparing the ground for a process of identifying grand challenges in mathematics education, Stephan et al. (2015) collected survey data from a wide range of relevant interest groups. They identified three main themes in the responses. The first of these was the challenge to change perceptions about what it is to do mathematics: "Respondents alluded to the challenge of helping people see that doing mathematics is about problem solving, reasoning, curiosity, and enjoyment, and not about following procedures to get 'the answer' or just about doing well on a test." (ibid., p. 139).

The educational trends of the latest three decades have shifted focus towards social aspects of learning and towards the pupil as an active participant engaged in explorative activities. Mathematics educators have been important contributors in this respect, as stereotypical views of mathematics and its practices seem particularly resistant against change. Devlin (2000) argues that true mathematical activity is motivating by nature as it connects the ubiquitous human capabilities of intellectualizing and socializing. Ricks (2009) elaborates on this view as he writes that "mathematical activity welds together the intellectual and social dimensions of human beings as they collaboratively wrestle with and jointly create mathematical terrain in a process of social mathematizing" (ibid., p. 8). Devlin and Ricks thus exemplify a view of mathematics as a social endeavor characterized by creative exploration, contradicting the stereotypical views of mathematics.

Educators worldwide are currently introducing "adaptive learning systems" in many mathematics classrooms. These computer programs create individualized learning experiences that include tailored learning material and frequent testing. They utilize information from these tests to select and present learning material adapted to the individual pupil's needs (Oxman & Wong, 2014). The rationale behind adaptive learning systems is evident: The teacher cannot help all pupils in a classroom at once. If a computer system can identify a pupil's achievement level, it can provide the pupil with targeted learning material and tasks. Considering the rapid technological development and current implementation rate, most mathematics educators will be acquainted with adaptive learning systems within few years.

In this article, we describe main characteristics of these computer systems and discuss their potential influence on pupils' views on mathematics. We will draw on Schoenfeld (1992) in describing the epistemological trends noted in the first two paragraphs and argue that the adaptive learning systems promote a view of mathematics that differs greatly from these.

Motivation and Aims

We investigated the development and implementation of a specific adaptive learning system from 2014 to 2017. In our experience, discussions about adaptive learning systems mainly evolved around issues of instrumental efficiency: Is this a more time- and cost-efficient way to develop mathematical skills than using existing approaches? Considering our own reception of the adaptive learning systems, we did not investigate critically the epistemological implications of these. Our current critical viewpoint developed gradually through interviews with teachers, group interviews with pupils and observations of pupils using the adaptive learning system.

The discussion in this article is not a new one. Researchers and practitioners have discussed computerized learning and its implications of such since the 60's and 70's. The reason we re-introduce this discussion is the current implementation rate in the Western world. We are most likely entering a time where a substantial share of Western pupils will be using adaptive learning systems in mathematics classrooms. Conclusively, the open problem we address in this article is the disproportionate relation between the high implementation rate on one side and the limited engagement in discussions about its implications on the other side.

Thus, we hope to achieve the following aims in this article:

- Aim 1: To familiarize mathematics educators with adaptive learning systems.
- Aim 2: To identify discrepancies between influential views on mathematical knowledge and the views fostered by adaptive learning systems.

Through the treatment of these aims, we seek to provide mathematics educators with important perspectives that applies not only to adaptive learning systems, but also to the general stream of educational technology. Indeed, the current advances in educational technological will result in many high-quality tools and learning activities. We believe this article will enhance mathematics educators' critical investigation of "the next big thing" that keeps coming along.

We will treat Aim 1 immediately as part of this introduction. After a presentation of the context and data material, we turn to Aim 2. We draw on Schoenfeld (1992) and others to present influential views on mathematical knowledge and discuss how adaptive learning systems relate to these ideas. Note that most developers of adaptive learning systems refer to theories of learning and not to theories of knowledge and knowing. Indeed, we do not want to make an unwarranted comparison between theories stemming from such different paradigms and, specifically, we will not engage in discussions about the efficiency of ALS learning in this article. We turn our attention towards the potential epistemological implications of the current generation of adaptive learning systems.

Adaptive Learning Systems (ALS)

Describing innovations in educational technology is like shooting at a moving target. Articles concerning these technologies are quickly outdated. Thus, our introduction to adaptive learning systems will draw on Oxman and Wong's (2014) rather general introduction. Their presentation encompasses many of the directions in which these systems are currently developing. In the remainder of this article, we will use "ALS" as an abbreviation of an "adaptive learning system". To increase readability, we will repeat the full term periodically.

Oxman and Wong (2014) provide an overview over basic characteristics of adaptive learning systems and important differences between such. In defining an ALS, they refer to the Office of Educational Technology in the U.S. Department of Education (2013):

> *Digital learning systems are considered adaptive when they can dynamically change to better suit the learning in response to information collected during the course of learning. (...) Adaptive learning systems use information gained as the learner works with them to vary such features as the way a concept is represented, its difficulty, the sequencing of problems or tasks, and the nature of hints and feedback provided.* (ibid., p. 27).

In many cases, the pupil will view a learning video before answering a set of question regarding that topic. The ALS will analyse these responses and either 1) consider that the pupil has achieved the foregoing learning goals thus present succeeding learning material to the pupil or 2) analyse the pupil's mistakes and present foregoing learning material according to the identified knowledge gaps. Consequently, a group of pupils using an ALS will quickly find themselves doing different tasks and spending time on different and personally adapted learning material.

Oxman and Wong presents three core elements of an ALS, namely, 1) the content model, 2) the learner model and 3) the instructional model. *The content model* refers to how the ALS organize and structure the mathematical content, at which points the ALS assesses the pupils and the different paths it directs the pupils in after assessment. Some systems have frequent and fine-meshed assessments while other systems deliver greater portions of content before more general assessments. Drawing on the pupil's responses, *the learner model* refers to how the ALS keeps track of the pupil's achievement level. Some systems might have a linear approach where the pupil receives an overall score which determines the further learning path. Other systems might keep track of the pupil's achievements at a sub-topic level and adapt the learning path accordingly.

The instructional model refers to the pedagogical principles underlying the decisions made by the ALS on the pupil's behalf. This is where the ALS combine information from the content model and the learner model and decide on which learning material to present when, either drawing on the accumulated or the most recent information about the pupil. The most sophisticated adaptive learning systems may not only provide successful learners with successive material. These systems may reduce the number of examples and explanations to the highest achievers, "minimizing the number of examples at each step, while guaranteeing that the model produced does not differ significantly from the one that would be obtained with infinite data" (Zliobaite et al., 2012, p. 49).

Most current adaptive learning systems are what Oxman and Wong classify as rule-based. In short, this is when the instructional model contains a series of if-then commands. The complexity varies greatly between systems. The simplest rule-based systems provide the pupil with an independent score after each assessment resulting in either "progress" or "take one step back". The complex systems involve results from several assessments and may result in a variety of outcomes, being different hints, repeated content or new content on the same material. The other class of systems are the algorithm-based systems. These are complex systems demanding great computational power. The ALS will develop the content model and learner model continuously, pairing them efficiently. Algorithm-based systems involve "data mining and advanced analytics to deal with big data, and employ complex algorithms for predicting probabilities of a particular student being successful based on particular content" (Oxman & Wong, 2014, p. 17).

Finally, we present Oxman and Wong's classification of the different degrees of adaptivity between different versions of an ALS. Some are minimally adaptive, some are adaptive at the assessment level and some are adaptive at both the assessment and the content level. A minimally adaptive ALS is a system that provides the pupil with specific responses targeting the specific mistakes the pupil did and refer the pupil to material to review. An ALS is adaptive at the assessment level if it in addition to the properties of a minimally adaptive ALS also uses previous assessments and ensures that the pupil does not progress until all necessary content is learned. An ALS that is adaptive at both the assessment and the content level has the properties of both foregoing systems. In addition, such an ALS will create an individualized learning path that "includes content that statistically has been shown to be most effective at filling in the knowledge gaps identified by the quiz" (Oxman & Wong, 2014, p. 28). The pupil will later receive a new assessment to ensure that the learning path has been successful.

Context and Data Material

Even though the aims of this article are primarily conceptual, the discussion draws on experiences made in the investigation of a specific adaptive learning system in the period from 2014 to 2017. We observed the development process from the very beginning at the drawing board in 2014 through a small pilot study in 2016 and a second pilot study in 2017.

During spring 2014, an educational technology enterprise, a local school community and the authors formalized a three-part collaboration for a governmental funded research-and-development project. The educational technology enterprise would be responsible for development of the adaptive learning system, the local school community would provide schools to the pilot studies and the authors, representing an independent research institute, would document the development and use of the innovation. The content of the adaptive learning system was analysis of functions and curves, which is part of the 11th grade mathematics curriculum in Norway. The target group was 11th grade pupils who had chosen the mathematics course which is most theoretically loaded. The pilot study in 2016 included two schools and the pilot study in 2017 included three schools, including one of the schools from the 2016 study.

The project group intended for the schools to apply the adaptive learning system in a majority of the lessons during a 2–4 week test period. Even though some classes used the adaptive learning system less frequently than the project group planned for, we learned significantly from these pilot studies. The pilot in 2016 mostly regarded technical and administrative processes and data from this is not very relevant in this article. In the 2017 pilot study, we focused on classroom use and outcome of this. The discussion in this article will mainly draw on experiences from the 2017 data collections.

Table 1: Data Material Collected in the 2017 Pilot Study.

School (#classes visited)	Classroom observations	Teacher interviews	Pupil interviews (4-6 pupils/group)
School A (4)	4	4	4
School B (3)	6	3	5
School C (4)	2	5	4
Total (11)	**12**	**12**	**13**

We developed an observational guide that we applied in our classroom observations. This guide consisted of three main parts: 1) Descriptive information about persons and learning activities. 2) Our interpretations of the pupils' responses to this introduction and their engagement with the adaptive learning system during class. 3) Open space to write ideas, considerations and illustrative events that emerged during the observations. Both authors were present in the first few classroom observations in order to calibrate our interpretations and use of the observational guide. Immediately after each lesson, the authors met to discuss their observations and first impressions.

We interviewed 12 teachers who had applied the adaptive learning system for at least one lesson. The interview guide was semi-structured and the main topics were their preparations before class, their evaluation of the adaptive learning system based on their current experiences, and their general considerations of strengths and weaknesses of such systems in mathematics education.

We interviews pupil in groups of 4-6, some at the end of a lesson, some immediately after a lesson and some a few weeks after the final lesson. This way, we hoped to detect a variety of pupil experiences and considerations. We selected pupils for group interviews in collaboration with the teachers in order to ensure a spread in gender and achievement level. In addition to the fixed topics of the interview guide, which concerned their considerations regarding the adaptive learning system, we confronted the pupils with some of our observations and encouraged them to elaborate these particular events. This resulted in valuable information and important validation of our interpretations (Robson, 2007).

Theory and Discussion

We treated Aim 1 in the "Adaptive Learning Systems" section. The forthcoming discussion will also provide input related to Aim 1. We will now turn our focus towards Aim 2, where we point to discrepancies between influential views on what constitutes as "mathematical knowledge" and the view fostered by adaptive learning systems. Schoenfeld's (1992) "Learning to think mathematically" will serve as a starting point to discover important epistemological characteristics of mathematics. This text holds high status in mathematics education and is among the most frequently referred texts in mathematics education. Even though more than 25 years have passed since Schoenfeld wrote this text, it is still highly relevant. Among many examples, we regard Boaler's (2015) "Mathematical mindsets" as a recent confirmation of the continued importance of these ideas, where she claims that mathematics is about creativity, sense making and communication. Following the presentation influential ideas, we discuss how adaptive learning systems and the activities facilitated by these systems relate to the presented ideas.

Influential Views on Mathematical Knowledge

Schoenfeld on What it means to Know Mathematics

Epistemology regards the nature of knowing and knowledge. Alan Schoenfeld (1992) treated such issues in a chapter of the 1992 handbook of research on mathematics teaching and learning. The chapter, entitled "Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics" has been reprinted several times. We refer to Schoenfeld to justify our interest in these issues here: "Simply put, a teacher's sense of the mathematical enterprise determines the nature of the classroom environment that the teacher creates. That environment, in turn, shapes students' beliefs about the nature of mathematics" (ibid., p. 71).

What, then, does Schoenfeld claim that mathematical knowledge consists of? First, we make a note about the beliefs pupils often hold: Mathematics is a collection of isolated procedures. Mathematics problems have only one correct solution, and there is only one correct way to solve them. You memorize the correct rule presented by the teacher and apply it as fast as you can. Schoenfeld and others (e.g., Lampert, 1990) claim that this understanding of mathematics is what pupils infer from years of mathematics classroom experience. In short, persons' beliefs about mathematics has received much attention (e.g., Forgasz & Leder, 2008; Markovits & Forgasz, 2017) and Schoenfeld's (rather negatively loaded) description from 1992 seem to prevail.

According to Schoenfeld, *knowing mathematics* means:

1. Exploration of patterns
2. Seeking understanding of mathematical structures and underlying relationships
3. Formulating and framing problems
4. Making conjectures
5. Justifying reasoning processes
6. Generalizing mathematical ideas
7. Communicating mathematical ideas

If these activities characterize mathematics classrooms, then "students will have opportunities to study mathematics as an exploratory, dynamic, evolving discipline rather than as a rigid, absolute, closed body of laws to be memorized" (National Research Council, 1989, p. 84). We will elaborate on three perspectives deduced from this list, namely, mathematics as an explorative activity (e.g., 1 and 2) where pupils have active agency (e.g., 3, 4, 5 and 6) and enact in a social context (e.g., 5 and 7).

Before doing so, we will comment on the role of formulas and procedures in mathematics. The description that follows paint a broad view of the nature of mathematical knowledge. However, this does not exclude formulas and procedures from being "real mathematics", nor does it exclude routine calculations from the set of basic mathematics skills. Schoenfeld includes this in his notion of mathematics, but claims that "a curriculum based on mastering a corpus of mathematical facts and procedures is severely impoverished – in much the same way that an English curriculum would be considered impoverished if it focused largely, if not exclusively, on issues of grammar" (Schoenfeld, 1992, p. 3).

Knowing Mathematics Means to Engage in Exploration

Drawing on e.g. Pólya's "How to solve it" (Pólya, 1945) and "Everybody counts", Schoenfeld (1992) elaborates on the importance of observations, testing, making estimations and guessing in mathematical work. Mathematicians spend much time analyzing problems and engaging in structured explorations before they devote themselves to a solution strategy. Some mathematics educators criticize school mathematics for portraying mathematics as a fixed set of formulas and procedures. Schoenfeld stresses the view of mathematical knowledge as the ability to explore patterns, systems and quantitative phenomena. This kind of knowledge enables pupils to solve problems where the starting points and the desired finishing points vary from context to context. Thus, school mathematics must enable pupils to navigate flexibly in the mathematical landscape and not only practice a set of predefined routes from fixed starting points to fixed finishing points. The landscape analogy stems from Skemp's (1976) definition of instrumental and relational understanding:

> *"The kind of learning which leads to instrumental mathematics consists of the learning of an increasing number of fixed plans, by which pupils can find their way from particular starting points (the data) to required finishing points (the answers to the questions). (…) In contrast, learning relational mathematics consists of building up a conceptual structure (schema) from which its possessor can (in principle) produce an unlimited number of plans for getting from any starting point within his schema to any finishing point." (Skemp, 1976, p. 25)*

According to Schoenfeld, the process of building up such a conceptual structure involves activities like activity 1 and 2 mentioned in the list above. Mathematicians will recognize creativity and explorative skills as crucial traits in mathematics. They spend little time conducting well-known routine calculations. However, they look for patterns, propose and challenge hypotheses, explore implications of new insights and make connections between previously disconnected areas. While computers do routine calculations, we depend on creative exploration to know what to calculate. Henningsen and Stein (1997) argue that these capacities develop in classrooms where pupils frequently can engage in dynamic mathematical activities and "rich" tasks. Contrasted to the view presented here is the view of mathematics as "a static, structured system of facts, procedures, and concepts" (ibid., p. 524). If mathematical tasks primarily depend on instrumental approaches with "right or wrong", this will contribute to the pupils' sense of what "doing mathematics" is all about (Schoenfeld, 1992).

Knowing Mathematics Means to Develop Mathematical Agency

Schoenfeld argues that teachers must engage pupils in activities where they get to make conjectures, where pupils' own questions get focus, where they develop their reasoning skills and where they get to explore own ideas. Activity 3, 4, 5 and 6 in the list all provide pupils with agency. According to this view, mathematics knowledge is not constrained to a fixed set of questions and tasks "out there" that the pupils need to learn the answers to, but it is a way for individuals to explore and solve challenges they themselves encounter. Returning to the Skemp analogy, school mathematics must not only provide pupils with a list showing possible routes in the landscape. Pupils must experience the excitement, joy and necessity of identifying where they want to go in this landscape. Having pupils formulate own problems and hypotheses, will transform the young girl or boy from a passive recipient to an agent engaged in meaningful activities. They receive responsibility when they have to justify their reasoning. In addition to the motivational aspects of providing pupils with agency and involvement, these experiences will foster a view of mathematical knowledge as something the pupils co-construct and contextualize. In a more recent publication, Schoenfeld (2014) argues that having to contribute in a collaborative learning process with own conjectures and justifying own reasoning to others are decisive elements in order to develop a mathematical identity.

Notably, opposed to routine calculations and applications of formulas presented by the teacher, such activities stimulate metacognitive activities. Schoenfeld writes about self-regulative processes involved in problem solving, namely, "monitoring and assessing progress 'on line', and acting in response to the assessments of on-line progress" (Schoenfeld, 1992, p. 58). He refers to Flavell (1976), who highlights the importance of active monitoring and consequent regulation and orchestration of learning processes. This is important not only to the learning of mathematics, but also to pupils' meta-learning. They need to become agents in their own learning processes. This includes the ability to assess the individual usefulness of activities in terms of learning, continuously to identify weak spots and knowledge gaps, and to organize a set of learning activities aimed at certain learning goals: Pupils need to "learn how to learn".

Knowing Mathematics Means to Engage in Collaboration and Communicate Mathematical Ideas

Schoenfeld concludes his section on this topic by stating that classrooms must be communities where pupils practice mathematical sense making. He argues that collaboration and communication have profound roles in what it constitutes to know mathematics. It is “an inherently social activity” (Schoenfeld, 1992, p. 3). Schoenfeld refers to many influential researchers (e.g. Deborah Ball, Lauren Resnick, Magdalene Lampert, Alba Gonzalez Thompson, etc.) and their writings in the 1980s to support this claim. Moreover, the many references to publications from interest groups in the same years (e.g. Everybody Counts, The NCTM Standards, different mathematics frameworks, etc.) exemplify why we can characterize the 80’s as the starting point for a shift of focus in mathematics education. Specifically, Lerman (2000) characterizes 1988 as the year of “the social turn” in mathematics education, due to the many influential texts published this year. The new theories described how social activities produce meaning, thinking and reasoning, contradicting the perspective of knowledge as “decontextualized mental objects in the minds of individuals” (Lerman, 2000, p. 13).

Schoenfeld goes beyond the view of collaboration as merely a way of learning. He claims that it is through participating in the “community of practice” that people develop an understanding of an enterprise. A community of practice is a “set of relations among persons, activity, and the world, over time and in relation with other tangential and overlapping communities of practices” (Lave & Wenger, 1991, p. 98), and the classroom is such a community. Taking this perspective, learning does not only happen *through* participation, but learning *is* increased participation. Knowing is thus being part of such a community, and knowing well is to have a high degree of participation. Exemplifying this, Tabach and Schwarz (2017) write that small-group work collaboration in mathematics has become “an educational goal rather than a means” (ibid., p. 273). Conclusively, knowing mathematics includes participation in a community of mathematics practitioners.

Implied by the participation in a community is the ability to communicate. Schoenfeld includes communication of mathematical ideas as part of what it means to know mathematics. Indeed, most educators have experienced how attempts to teach have revealed shortcomings in own understanding of the teaching material. Knowing mathematics means being able to communicate mathematical ideas and arguments to others.

Relating Adaptive Learning Systems to Core Views on Mathematical Knowledge

In the foregoing section, we used Schoenfeld (1992) as a starting point as we prestented epistemological views on mathematics that have influenced the mathematics education community for several decades. Knowing mathematics means, among other things, to engage in 1) mathematical exploration as an 2) active agent who 3) contributes in a learning community. We now draw on these three mentioned perspectives as we discuss some main characteristics of adaptive learning systems (ALS). At the end of this section, we make a note on the potential of ALS in mathematics classrooms.

From Exploration to Procedures

Mathematics education literature suggests that teachers provide pupils with opportunities to explore, to propose questions and make conjectures, and to engage in "rich tasks" and open-ended questions. The pupils' learning paths in such environments differ greatly. The activities facilitated by adaptive learning systems have other characteristics. Developers of adaptive learning systems define a content model. This model depicts how the mathematical content appears in the ALS: Which topics link to other topics? In which order do they occur for the different learners? Which possible routes may pupils take between topics? How much content do the ALS present before pupils receive an assessment?

The content model is, indeed, what Henningsen and Stein (1997) described as a static, structured system of facts, procedures, and concepts. Pupils who make their own discoveries and find similarities and associations between different mathematical topics, are unable to pursue this in an ALS, where connections between content are predefined. Drawing on the Skemp "mathematics is a map" analogy, an ALS provides practice in moving along certain routes on the map. However, the minute your starting point is on a street only a block away from your practiced route, you do not know how to navigate, and if you desire to take an experimental route or see if you can go somewhere else, the systems pushes you back onto the predefined track. An ALS does not support this kind of playful experimentation in the quantitative landscape, which is how pupils develop relational understanding. Even though some adaptive learning systems have detailed and fine-meshed content models, a complete decomposition of mathematics into single components with fixed relations to other components, reduce the number of paths pupils can take in the mathematical landscape. The content model defines how deep into the material pupils can go and which routes they should take between topics.

Pupils who make the same mistakes will experience the same learning path. This path contains a large body of closed questions, as this generation of adaptive learning systems are unable to process answers to open-ended and explorative questions. The instructional model draws on pupils' right or wrong answers in an instrumental way, which Schoenfeld (1992) suggested might contribute to pupils' sense of what "doing mathematics" is: pupils learn implicitly that having mathematical knowledge means knowing the single correct answer to a set of predefined questions, and knowing a set of procedures is what knowing mathematics is all about.

From Being Agents to Being Respondents to a Fixed Body of Knowledge

Adaptive learning systems differ in how the instructional model responds to the learner model. Many systems will utilize both the pupils' assessment scores and the learner model. A high quality and sophisticated ALS will develop complex learner models. It identifies not only the overall ability level of the pupil, but it continuously learns about the approaches that seems most successful for the individual pupil.

Still, an ALS will have to rely on a set of predefined learning trajectories (e.g., Simon 1995). This has important implications regarding mathematical agency. Firstly, an ALS cannot facilitate the activities which according Schoenfeld increases agency, e.g. proposing own problems and conjectures, finding own ways of describing phenomena and justifying mathematical reasoning. An ALS cannot respond to creative suggestions or provide pupils with agency as producers of mathematical content. Knowing mathematics in the ALS sense means, as it seems for the pupils, mastering the "naturally given set of challenges". Thus, pupils become respondents to a fixed body of knowledge as opposed to being engaged in activities they have initiated and defined.

Secondly, we can only regard the optimization provided by an ALS as "optimal" within the universe of learning elements implemented in the system. At a certain point in the learning process, a pupil may benefit from input or actions that a computer system cannot implement. Thus, the pupils lose agency not only with respect to what mathematical knowledge consists of, but also with respect to how they come to know mathematics. They are passive recipients of a learning path and a predefined and limited set of learning activities. The pupils are recipients and not agents in the learning process. This side effect of widespread use of ALS relates to what Schoenfeld describe as self-regulative processes. When asked about the main purpose of formal education, people often use the phrase "learning how to learn". Pupils need agency to develop their meta-learning abilities. The main idea of an ALS is to use the learner model to map the pupil's ability level on the pupil's behalf and to use the instructional model to select learning activities on the pupil's behalf. If the ALS is sophisticated, it will also evaluate the success of this learning strategy on the pupils' behalf. In short, an ALS deprives pupils of meta-learning experiences. The pupils do not need to identify own ability level, propose learning strategies or evaluate these.

From Collaboration and Communication to Individual Isolation

Contrary to the social turn in mathematics education, an adaptive learning system (ALS) mainly facilitates individual activities. Pupils equip with a headset and work isolated from the classmates. The instruction model of an ALS depends on accurate input to the learner model in order to provide an adapted learning experience. Thus, any interference from teachers or other pupils is inappropriate. If the pupil receives guidance from other persons, the learner model will be imprecise and consequently the instruction model will not succeed in providing a well-adapted learning path. Pupils confound the adaptivity if they collaborate.

According to the views on mathematical knowledge presented in this article, pupils need to learn to take part in a mathematical discourse and to communicate mathematics efficiently. This generation of adaptive learning systems cannot facilitate any kind of training in communication, as its opportunities to assess pupils' open-ended ideas and explanations are limited. Nor does it facilitate fruitful group discussions and participation in a learning community, as pupils after an ALS session will have been working on different assignments and topics.

This setting, where pupils can complete a full mathematics course alone with headsets, where collaboration confound the learning process and where communication is absent, may influence their view on mathematical knowledge. It is restricted to the achievements you can attain as an isolated individual.

This issue relates to the issue of mathematical agency. The pupils develop their mathematical identities through interaction with other persons, as they contribute in a mathematical discourse and receive direct or indirect feedback from other persons. They receive few identity clues through listening to learning videos, responding to computer assigned tasks and having the responses labelled "correct" or "incorrect". Begin an active mathematical agent depends on a well-established mathematical identity, which develops partly due to meaningful interaction with other persons. In her recent research commentary "Authority, identity, and collaborative mathematics", Langer-Osuna (2017) elaborates on this issue.

The Potential of Adaptive Learning Systems

The above limitations provide an argument for why an ALS cannot take up a substantial amount of the time pupils spend in the mathematics classroom. We argue that this may foster a narrow view of what it means to know mathematics.

Irrespective of this critique, we suggest that an ALS has potential to contribute positively to school mathematics. An ALS facilitates individual activities, but this is both welcome and necessary in some learning contexts. When pupils do homework, we cannot assume that other persons are present for guidance or collaboration. The interactivity and adaption provided by an ALS is preferable to no interaction or adaption at all. Moreover, when a class is practicing for a test or repeating learning material, the pupils may benefit from working individually on the specific topics that they themselves need to repeat. An ALS can be efficient in this respect, providing the pupils with training on topics they do not master sufficiently.

Indeed, mathematics is more than procedural knowledge, but such knowledge is part of an important basis. All pupils need to spend some time practicing basic algorithms. Thus, we consider the potential of adaptive learning systems in homework, in practicing routine skills and in repetition to be promising.

Conclusion and Future Research

Conclusion

In this article, we presented basic characteristics of adaptive learning systems (Aim 1) and discussed the view of mathematical knowledge they may foster (Aim 2). Summarizing our critique, the adaptive learning systems provide mathematical activities where pupils move around in the system according to predetermined patterns unable to explore own insights and ideas. They are not in control of their own learning process and the activities are utterly individual endeavors. Widespread use of such systems may contribute to pupils developing a narrow view of mathematical knowledge as procedural, fixed and individualistic.

Conclusively, the current generation of adaptive learning systems should not occupy much time in mathematics classrooms. We encourage teachers and school leaders planning to use ALS to discuss the following claim: "Widespread use of an ALS in mathematics classrooms will provide pupils with a narrow view of what mathematics is, namely, procedural, static and individualistic." Such a discussion may support a thoughtful implementation of an ALS, for instance when pupils practice procedural skills as homework or before exams.

Future Research

With regard to the epistemological issues raised in this article, we expect future investigations of how adaptive learning systems actually, and not hypothetically, influence pupils' views on mathematics. Will anyone succeed in creating an ALS without the weaknesses elaborated on in this article? Will the next generation of ALS include activities where pupils explore own ideas and make knowledge connections in a learning community? Alternatively, will the limited scope of such systems influence the constant negotiation of the content of school mathematics?

With regard to theories of learning, both teachers, school owners and technology developers are curious about the efficiency of adaptive learning systems. Do the adaption provided by an ALS exceed the value of the existing adaption, where pupils support each other, choose exercises from targeted difficulty levels and spend time on the exercises they answered incorrectly? Where teachers who know their pupil's learning history and preferences can spend a minute or two providing targeted support?

Despite the critique presented in this article, we hope to find adaptive learning systems in many mathematics classrooms in the future. It relies on a collective effort of teachers, ALS developers and mathematics education researchers to ensure the quality of these.

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References

Boaler, J. (2015). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. San Francisco, CA: Jossey-Bass.

Devlin, K. J. (2000). *The math gene: How mathematical thinking evolved and why numbers are like gossip.* New York: Basic Books.

Flavell, J. (1976). Metacognitive aspects of problem solving. In L. Resnick (Ed.), *The nature of intelligence* (pp. 231–236). Hillsdale, NJ: Erlbaum.

Forgasz, H. J., & Leder, G. C. (2008). Beliefs about mathematics and mathematics teaching. In P. Sullivan & T. Wood (Eds.), *International handbook of mathematics teacher education: Vol. 1. Knowledge and beliefs in mathematics teaching and teaching development* (pp. 173–192). Rotterdam/Taipei: Sense Publishers.

Henningsen, M., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education, 28*(5), 524–549.

Lampert, M. (1990). When the problem is not the problem and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal, 27*(1), 29–63.

Langer-Osuna, J. M. (2017). Authority, identity, and collaborative mathematics. *Journal of Research in Mathematics Education, 48*(3), 237–247.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Lerman, S. (2000). The social turn in mathematics education research. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 19–44). Westport, CT: Ablex.

Markovits, Z., & Forgasz, H. J. (2017). “Mathematics is like a lion”: Elementary students’ beliefs about mathematics. *Educational Studies in Mathematics, 96*(1), 49–64.

National Research Council. (1989). *Everybody counts: A report to the nation on the future of mathematics education.* Washington, DC: National Academy Press.

Oxman, S., & Wong, W. (2014). *White paper: Adaptive learning systems*. DV X/DeVry Education Group and Integrated Education Solutions.

Pólya, G. (1945). *How to solve it*. Princeton: Princeton University.

Ricks, T. E. (2009). Mathematics is motivating. *The Mathematics Educator, 19*(2), 2–9.

Robson, C. (2007). *Real world research: A resource for social scientists and practitioner-researchers.* Oxford: Blackwell Publishers.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334–371). New York: Macmillan.

Schoenfeld, A. H. (2014). What makes for powerful classrooms, and how can we support teachers in creating them? A story of research and practice, productively intertwined. *Educational Researcher, 43*, 404–412.

Simon, M. A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education, 26*, 114–145.

Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Mathematics Teacher, 77*, 20–26.

Stephan, M.L., Chval, K.B., Wanko, J.J., Civil, M., Fish, M.C., Herbel-Eisenmann, B., Konold, C., & Wilkerson, T.L. (2015). Grand challenges and opportunities in mathematics education research. *Journal for Research in Mathematics Education, 46*(2), 134–146.

Tabach, M. & Schwarz, B. B. (2017). Professional development of mathematics teachers toward the facilitation of small-group collaboration. *Educational Studies in Mathematics, 97*(3), 273–298.

U.S. Department of Education, Office of Educational Technology (2013). Expanding evidence approaches for learning in a digital world. Washington D. C.

Zliobaite, I., Bifet, A., Gaber, M., Gabrys, B., Gama, J., Minku, L., & Musial, K. (2012). Next challenges for adaptive learning systems. *SIGKDD Explorations, 14*(1), 48–55.

The Power of Inductive Reasoning in Mathematics Competitions

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Introduction

It is common to hear children as young as four years old utter the statement "all birds can fly". This statement might seem rather ordinary and insignificant at first. However on closer scrutiny, one would discover that this statement holds plenty of weight. Why is that so? Because for children to conclude that "all birds can fly", it seems to suggest that they have seen all species of birds and can therefore arrive at that remarkable conclusion. In reality however, it is extremely unlikely that children of that age have seen all species of birds available to make that conclusion, let alone experienced scientists who spend their lifetime studying birds. So how then are they able to arrive at that conclusion? What thinking processes are behind the statement that "all birds can fly"?

Inductive Reasoning

The ability to observe characteristics or properties about living things or inanimate objects in the surrounding natural environment and notice patterns is a natural inclination of the human mind (Mason, 1996). This inadvertently allows us to obtain scientific knowledge (Polya, 1945). It is second nature to observe that a few species of birds, such as crows or seagulls, can fly and naturally extend this reasoning to all other types of birds. Such is known as inductive reasoning, which is a process of analysing particular cases or observations and inferring to arrive at a general conclusion or rule (Polya, 1945). In other words, reasoning from particular instances is extended across all instances in order to reach a general conclusion. This is contingent upon detecting similarities across cases, which is espoused by Klauer (1988), and consists of looking for patterns and relationships within the given numerical data and figures (Neubert & Binko, 1992). According to Klauer (1988, 1992), inductive reasoning involves methodically and rigorously comparing objects with the ultimate objective of seeking out similarities and differences amongst the specific cases or relations. One can therefore say that inductive reasoning adds to the presently available information (Klauer, 1999) which is not an easy feat. In fact, inductive reasoning has even been considered as an ability to produce fresh perspectives, a productive characteristic of humans (De Koning et al., 2003; Sternberg & Gardner, 1983).

Importance of Inductive Reasoning

Since inductive reasoning is such a natural ability of the human mind, its importance to human society cannot be undermined. It is central to general human intelligence (Carroll, 1993) which underpins the performance in complex tasks from different subject content areas. The integral and foundational role that inductive reasoning plays in mathematics learning and problem solving (NCTM, 2000) is testament to its centrality and importance in human development. It is pervasively present and useful in many problem solving activities (Nisbett et al., 1983) and is therefore commonly used by many mathematics educators (Polya, 1954). In addition, inductive reasoning has been found to play an important role in developing expertise in a skill or content domain and has even been said to predict academic performance and test scores well (Pellegrino & Glaser, 1982).

Inductive reasoning, being such an important ability in mathematics, can therefore be said to be fundamental to problem solving involving higher order thinking (HOT) skills. Behind the acquisition of HOT skills lies the ability to recognize patterns and generalise, which constitutes inductive reasoning. This ability is closely associated with a person's knowledge of numbers and being able to identify relations within numbers (Haverty et al., 2000). Having "number sense", which is having an instinctive feel for numbers together with its uses, interpretations and relationships (NCTM, 1991; Howden, 1989), underpins all these. According to Greeno (1991), "number sense" includes capabilities such as being able to flexibly compute mentally, estimation of numerical data and evaluation. All these can be developed in stages through exploration of numbers in various contexts and drawing relationships between them without being subjected to the constraints of available algorithms or formulas (Howden, 1989).

The Singapore Mathematical Olympiad

A context where "number sense" is pushed to its limits is mathematics competitions. In such competitions, knowledge is extended beyond the confines of the school curriculum to help students inculcate an appreciation for mathematics and learn advanced mathematical thinking skills which would not have been accorded primary importance in the school curriculum (Toh, 2012). A mathematics competition that perhaps best embodies the extension of knowledge beyond the school curriculum is the Singapore Mathematical Olympiad (SMO), which is arguably the most eminent national mathematics competition in Singapore. Every year, the SMO garners the most number of participating students in Singapore and information is readily available from the Singapore Mathematical Society publications (Toh, 2012). According to official documents, the objectives of the SMO are two-fold; (1) to test the ingenuity and mathematical problem-solving ability of participants, and (2) to discover and encourage mathematical talents in Singapore schools (Chua, Hang, Tay & Teo, 2007).

Objectives of Paper

With the two objectives of the SMO in mind, it is not hard to see the importance of having good "number sense" to effectively reason inductively in problem solving contexts. Since inductive reasoning is so vital, how then does it feature in the SMO? How do the questions in the SMO enunciate the features of inductive reasoning? How can inductive reasoning be used as a cognitive strategy to tackle questions in the SMO? These are questions that would be of interest in this paper. Hence, the main aim of this paper is to illustrate the importance of inductive reasoning in the context of the SMO questions by showing that it is an important cognitive tool for solving SMO problems.

Inductive Reasoning in SMO Problems

To illustrate how inductive reasoning can be utilized in SMO problems, it is first necessary to reiterate what inductive reasoning is. Inductive reasoning, as seen from the above review of literature, is the process of analysing particular cases or observations and inferring to arrive at a general conclusion or rule. In the process of analysing particular cases, similarities, patterns and relationships are being drawn. The analysis of particular cases can be a very powerful vehicle or strategy for approaching problems such as those depicted in Figure 1.

Q1.

Among the five numbers $\frac{23}{44}, \frac{24}{45}, \frac{25}{46}, \frac{26}{47}$ and $\frac{27}{48}$, which one has the smallest value?

(A) $\frac{23}{44}$ (B) $\frac{24}{45}$ (C) $\frac{25}{46}$ (D) $\frac{26}{47}$ (E) $\frac{27}{48}$

(SMO 2017)

Q2.

The last two digits of 9^{2004} is

(A) 21 (B) 81 (C) 09 (D) 61 (E) 01

(SMO 2004)

Figure 1. Two SMO Questions of Inductive Reasoning Type 1.

As calculators are not allowed in SMO, it would be very difficult to tell which number has the smallest value without converting the five numbers into a decimal form in Q1. As such, another strategy is needed to determine which number is the smallest. Using the idea of analysing particular cases, a particular case can be conjured that mirrors the ordered sequence of five numbers in Figure 1. Instead of using integers that are relatively large in both numerators and denominators, smaller integers could be used to draw a parallel. For instance, and could be used as a particular case that parallels the numbers in Figure 1. This set of numbers would be more manageable as it is not difficult to convert them to decimals without the use of a calculator. One would notice that the numbers are indeed increasing from left to right. To induce from this observed pattern, another case can be examined to confirm that this observation is indeed applicable. For example, the case of and   can be used to validate the pattern observed earlier. One would notice again that the numbers increase from left to right, thus adding credibility to the pattern observed earlier. With these two particular cases, one can therefore extend the reasoning beyond and reason inductively to reach the conclusion that the same pattern applies to the sequence of five numbers in Q1 of Figure 1.

Q2 is not much different from Q1 in terms of the content knowledge and reasoning required. As with Q1, particular cases can be considered to find a pattern. In this case, it can be observed that , , , , , etc. One would notice that the last digit of each number repeats in a pattern, 9 and 1, for every two numbers. This observed pattern can be extended beyond those given above and one can arrive at the conclusion that the last digit of is 1. However, looking for a pattern for the second last digit is more tedious as more numbers need to be written out to find a pattern as seen in Table 1 below.

Table 1. Multiples of 9

9^1 = 09	9^{11} =…09
9^2 = 81	9^{12} =…81
9^3 =..29	9^{13} =..29
9^4 =..61	9^{14} =..61
9^5 =…49	9^{15} =…49
9^6 =…41	9^{16} =…41
9^7 =…69	9^{17} =…69
9^8 =…21	9^{18} =…21
9^9 =….89	9^{19} =…..89
9^{10} =….01	9^{20} =…..01

At this juncture, it would become apparent that the last two digits repeat for every 10 numbers and the pattern repeats again after . This pattern can then be extended beyond and inductive reasoning can be performed. Therefore, for , the last two digit would occur at the fourth position, meaning that the last two digits of are the same as the last two digits of .

Both questions in Figure 1 do not require advanced mathematical content knowledge and can be classified as a Category 1 question according to Toh (2012). However, for the purposes of this paper, the questions in Figure 1 shall be categorised as “inductive reasoning type 1”, which does require any advanced mathematical content knowledge.

Another example of questions that highlight the power of inductive reasoning is shown in Figure 2, which shall be categorised as “inductive reasoning type 2”. Such questions involve additional content knowledge of basic algebraic identities or other simple results such as the laws of logarithms.

Q3.
Find the value of

$$\sqrt{1+2017\sqrt{1+2016\sqrt{1+2015\sqrt{1+2014\sqrt{1+2013\times 2011}}}}}.$$

(SMO 2017)

Q4.
Suppose that a, b and c are real numbers greater than 1. Find the value of

$$\frac{1}{1+\log_{a^2b}\left(\frac{c}{a}\right)}+\frac{1}{1+\log_{b^2c}\left(\frac{a}{b}\right)}+\frac{1}{1+\log_{c^2a}\left(\frac{b}{c}\right)}.$$

(SMO 2009)

Figure 2. Two SMO Questions of Inductive Reasoning Type 2.

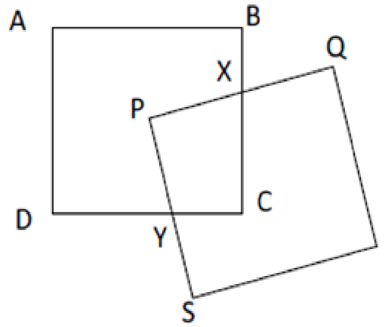
In the case of Q3, a relation needs to be made to an algebraic identity, $(a + b)(a - b) = a^2 - b^2$ before inductive reasoning can occur. 2013 can be expressed as 2012 + 1 while 2012 - 1 yields 2011. This would imply that 2013 2011 = 2012^2 - 1, which means that . The same idea can be used for which will give 2013. At this point, a clear pattern has emerged and it can be induced that the final step is .

Q4 is a very interesting question involving the knowledge of the laws of logarithm. At first glance, it seems that applying the laws of logarithm might suffice. However, on closer inspection, one would realize that elements of inductive reasoning are present also. One would be able to observe that the denominator, , in the first algebraic fraction can be simplified to using the law of logarithms. This implies that the first algebraic fraction is now . Similarly, the second algebraic fraction can be simplified to . At this point, a pattern can be observed in the way both algebraic fractions are simplified and one would notice that the denominators are while the numerators follow the pattern in the base of the logarithmic function, , in the denominator of each fraction. This pattern can be extended to the third algebraic fraction. It is evident therefore that some form of inductive reasoning is present in such a question.

A third level of inductive reasoning that can be gathered from the SMO past year questions is the idea of relating to a "special" case or considering cases. This involves finding a similarity between the given question, a particular case, and drawing a connection to another "special" case or cases where the problem can be solved in a more simplified and manageable way. Such inductive reasoning will be known as "inductive reasoning type 3” as seen in Q5 and Q6 in Figure 3.

Q5.

In the following figure, ABCD and PQRS are two identical squares with side 20cm. The point P is placed at the centre of the square ABCD. What is the area of the quadrilateral PXCY in cm^2?



(SMO 2004)

Q6.

You have 30 rods of length 5, 30 rods of length 17 and 30 rods of length 19. Using each rod at most once, how many non-congruent triangles can you form?

(A) 6 (B) 7 (C) 8 (D) 9 (E) 10

(SMO 2017)

Figure 3. Two SMO Questions of Inductive Reasoning Type 3.

To simplify the problem in Q5, a “special” case where PQ is parallel to AB can be considered. In doing so, one must be able to visualize that quadrilateral PXCY has the same area as the quadrilateral formed when PX is parallel AB. This is accomplished by rotating the square PQRS clockwise about the point P until PX becomes parallel to AB. A smaller square would be obtained whose area can be calculated easily by taking cm^2. The key to using a “special” case is to identify a similarity and draw a connection from the given case to the “special” case, which is part of inductive reasoning.

In Q6, different cases need to be considered in order to find the number of non-congruent triangles that can be formed. The similarity that needs to be present is the non-congruence of the triangles formed and the fact that each rod cannot be connected to form a longer rod, as implied by the statement “using each rod at most once”. Through a mere listing of the possibilities, one would discover that there are eight different triangles that can be formed. Considering the case that 3 rods are of the same length, three equilateral triangles can be formed of lengths 5 by 5 by 5, 17 by 17 by 17 and 19 by 19 by 19. The case that 2 rods are of the same length and 1 rod of a different length needs to be considered next. For that, four isosceles triangles can be formed with lengths 17 by 17 by 5, 17 by 17 by 19, 19 by 19 by 5 and 19 by 19 by 17. One more case needs to be considered where the lengths of the triangle are 5 by 17 by

19. Hence, a total of eight different triangles can be formed.

Table 2 summarizes the various types of inductive reasoning as established with reference to past year SMO questions.

Table 2. Different Types of Inductive Reasoning in SMO Questions.

Type of Inductive Reasoning	Description
Inductive Reasoning Type 1	Problems that do not require advanced mathematical content knowledge and rely largely on the process of inductive reasoning.
Inductive Reasoning Type 2	Problems that require requisite mathematical content knowledge and rely on the process of inductive reasoning.
Inductive Reasoning Type 2	Problems that require reference to a “special“ case or considering cases and rely on the process of inductive reasoning.

Implications for Teaching & Learning

Inductive reasoning is pervasively present in SMO questions as demonstrated above. It is therefore imperative that elements of inductive reasoning be made explicit in the mathematics teaching pedagogy, particularly in training students for mathematics competitions such as the SMO. On top of the requisite mathematical content knowledge, students should be taught to make observations or hypotheses about particular cases and test them with other cases. Once the hypothesis is shown to be applicable to other cases, it can be extended to all cases and a generalisation can be subsequently induced.

However, caution needs to be exercised when engaging in inductive reasoning as there could be the possibility of cases that do not conform to the generalisation induced from particular cases. This is best illustrated by examining the statement in the introductory section which states that “all birds can fly”. A counterexample needs to be found to disprove this statement made as a result of inductive reasoning. In this case, one can point out that penguins, despite being birds, do not have the ability to fly. Thus, it is pertinent to also give opportunities for students to look for counterexamples to disprove their generalisations. All that is required is a single counterexample and the conclusion derived from inductive reasoning immediately fails.

In some instances, a distinct pattern could be hard to observe due to the sheer magnitude of the numbers. An example would be Q2 in Figure 1. A sufficiently large number of cases need to be foregrounded in order to discover the pattern with the second last digit of each case. Hence, inductive reasoning might appear to be tedious but when accomplished, brings about an elegant solution to a perceived complex problem.

Conclusion

The objective of this paper is to demonstrate the importance of inductive reasoning in the SMO through showing that inductive reasoning can be used as a cognitive strategy to approach a variety of SMO questions. As highlighted above, relying solely on inductive reasoning to solve SMO questions is insufficient as a certain requisite level of mathematical content knowledge is also required. This was clearly portrayed in types 2 and 3 of inductive reasoning in Table 1. Despite that, it is undeniable that inductive reasoning is a fundamental and integral aspect of the SMO competition and mathematics in general. Therefore, there is great value in emphasizing inductive reasoning as a way of approaching mathematics problems and also as a cognitive strategy to solve mathematics problems, especially in mathematics competitions such as the SMO.

References

Carroll, J. B. (1993). *Human cognitive abilities*. *A survey of factor-analytic studies*. Cambridge, MA: Cambridge University Press.

Chua, S. K., Hang, K. H., Tay, T. S., & Teo, T. K. (2007). Singapore Mathematical Olympiads: 1995 – 2004. Singapore: Singapore Mathematical Society.

De Koning, E., Sijtsma, K., & Hamers, J. (2003). Construction and validation of a test for inductive reasoning. *European Journal of Psychological Assessment*, *19*(1), 24 - 39.

Greeno, J. G. (1991). Number sense as situated knowing in a conceptual domain. *Journal of Research in Mathematics Education*, *22*, 170–218.

Haverty, L. A., Koedinger, K. R., Klahr, D., & Alibali, M. W. (2000). Solving inductive reasoning problems in mathematics: not-so-trivial pursuit. *Cognitive Science*, *24*(2), 249 - 298.

Howden. H. (1989). Teaching number sense. *Arithmetic Teacher*, *36*(6), 6 - 11.

Klauer, K. J. (1988). Paradigmatic teaching of inductive thinking. In H. Mandl, E. De Corte, N. Bennett, & H. F. Friedrich (Eds.), *Learning and Instruction*, *Vol. 2* (pp. 23 - 45). Oxford, UK: Pergamon Press.

Klauer, K. J. (1992). Teaching inductive reasoning to highly able children. *European Journal for High Ability*, *3*, 164 - 180.

Klauer, K. J. (1999). Fostering higher order reasoning skills: the case of inductive reasoning. In J. H. M. Hamers, J. E. H. Van Luit, & B. Csapo (Eds.), *Teaching and learning thinking skills* (pp. 131 - 155). Lisse, The Netherlands: Swets & Zeitlinger.

Mason, J. (1996). Expressing generality and roots of algebra. In N. Bednarz, C. Kieran & L. Lee (Eds.), *Approaches to algebra: Perspectives for research and teaching* (pp. 65 - 86). Dordrecht, The Netherlands: Kluwer Academic Publishers.

National Council of Teachers of Mathematics (NCTM). (1991). *Developing number sense in the middle grades*. Reston, VA: NCTM.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Nisbett, R. E., Krantz, D. H., Jepson, C., & Kunda, Z. (1983). The Use of Statistical Heuristics in Everyday Inductive Reasoning. *Psychological Review*, *90*(4), 339 - 363.

Pellegrino, J. W., & Glaser, R. (1982). Analyzing aptitudes for learning: Inductive reasoning. In R. Glaser (Ed.), *Advances in instructional psychology* (Vol. 2). Hillsdale, NJ: Lawrence Erlbaum Associates.

Polya, G. (1945). *How to solve it* (2nd ed.). New York: Doubleday.

Polya, G. (1954). *Induction and analogy in mathematics: Volume I of Mathematics and plausible reasoning*. Princeton, NJ: Princeton University Press.

Sternberg, R. J., & Gardner, M. (1983). Unities in inductive reasoning. *Journal of Experimental Psychology: General*, *112*, 80–116.

Toh, T. L. (2012). *The roles of mathematics competitions in Singapore mathematics education*. Paper presented at 12th International Congress on Mathematical Education (ICME-12), July 2012, Seoul, Korea.

Social Interactions in an Online Environment: Developing Mathematical Process Standards

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Introduction

Teaching and learning in an online environment is a new delivery method when compared to the instructions methods that have been in place for decades. In fact, for many students, your online math class might be their first course they have ever taken online. Compare this to the hundreds of classes that they have had face-to-face throughout their years in K-12 classes. Even if you are teaching your course in a blended, or hybrid, method or completely face-to-face with online activities, students rarely have experience in this form of instruction. Experience is lacking even more so for an instructor who has not had the opportunity to take, let alone teach, online mathematical instruction. Preparing lesson plans and instruction in an online environment takes intentional thought upon not only what our students learn, but how they learn. One such way to develop lessons in online math classes is to focus not just upon the content to be learned, but also on the desired processes you want from students.

Matching Online Learning to Processes

John Dewey once stated, "If we teach today's students as we taught yesterday's, we rob them of tomorrow." Much of the current online mathematical instruction is centered around drill and practice with videos constituting the drill by replacing traditional lecture, and adaptive learning systems such as **A**ssessment and **LE**arning in **K**nowledge **S**paces (ALEKS) from McGraw-Hill or MyMathLab from Pearson invoking the practice with problem sets. While this method has its advantages with regards to time flexibility and instantaneous feedback, there exist some limitations as well. These limitations include a lack of assessment to the process standards set forth by NCTM. One such process is the ability to communicate mathematical thinking coherently and clearly to peers and teachers as referenced in the NCTM process standard of mathematics communication (NCTM, 2000). Traditionally, it is very common in online mathematics learning environments for student-student and student-teacher interactions to be minimal (Hawkins, Barbour, & Graham, 2012). Students end up working in isolation on math assignments away from the guidance of an instructor or fellow students limiting the social interaction skills which are vital to build meaning and permanence of ideas.

This isolation is magnified even further when it comes to student retention and struggling students. Limited student and teacher interactions are associated with increased student fear and anxiety, negatively impacting student motivation (Murphy & Rodríguez-Manzanares, 2008). Higher anxiety and lower motivation result in lower retention rates. Babson Survey Research Group (2013) found that academic leaders believe lower retention rates in online courses is a main barrier to the growth of online instruction. Therefore, it is theoretically possible that an increase of social interactions in an online mathematics classroom will not only help with improving and assessing student communication, but also reduce the amount of anxiety and fear students feel and thus improve retention rates in online courses.

Additionally, while drill and practice help many of our students learn procedural knowledge and algorithms, it fails to assess our students' learning of the conceptual understanding needed for proper communication. The focus of this lesson plan was built around the process of communication for Foundations for Algebra, an undergraduate developmental math course, with the intent purpose of increasing the potential for social interactions. Finding ways to add social interaction in an online mathematics environment is still a new concept.

Planning the Lesson

This online lesson was intentionally designed to be utilized in a variety of undergraduate mathematics courses with differing content. Meaning, the outcomes would be focused upon targeted mathematical process of communication rather than teaching to one particular area of study or course. The advantage of this approach is that the lesson plan can be adaptable to many different content topics (from adding and subtracting fractions in developmental math to the chain rule formula in Calculus). As well, the lesson would focus on authentic learning situations outside of a classroom environment.

Procedural Knowledge

How can we better prepare our students to learn outside of the academic environment and to help with transfer of knowledge? Many people access Google, and more particularly YouTube, for quick recall of knowledge – and in a much more authentic manner of learning, students share content over social media websites. Learning to improve this form of communication and dissemination of information will help our students in transferring mathematics into their everyday life. Helping students to better understand how to find and search the never-ending library of resources on procedural knowledge is an extremely helpful process and provides a foundation for becoming an intelligent consumer of mathematics.

Lesson Plan

The lesson content chosen was upon the addition and subtraction of fractions in an undergraduate remedial math course, Foundations for Algebra. However, as mentioned previously, the specific topic is not as important as the manner in which students engaged with the content, which was developed to attend to the mathematical process standard of communication. Therefore, the activity can be replicable into any online mathematics instructional course. There were three major activities positioned to take the place of traditional instruction, (a) Video Reflections, (b) Finding and Sharing Content, and (c) Rating Videos. Because the focus of the lesson was on the process standard of communication necessary for students to learn this material, the level of practice problems was reduced. These lessons were distributed to students through Canvas, the Learning Management System (LMS) at the university but could easily be added into any LMS at any institution. The format of the lesson instruction is demonstrated in Figure 1.

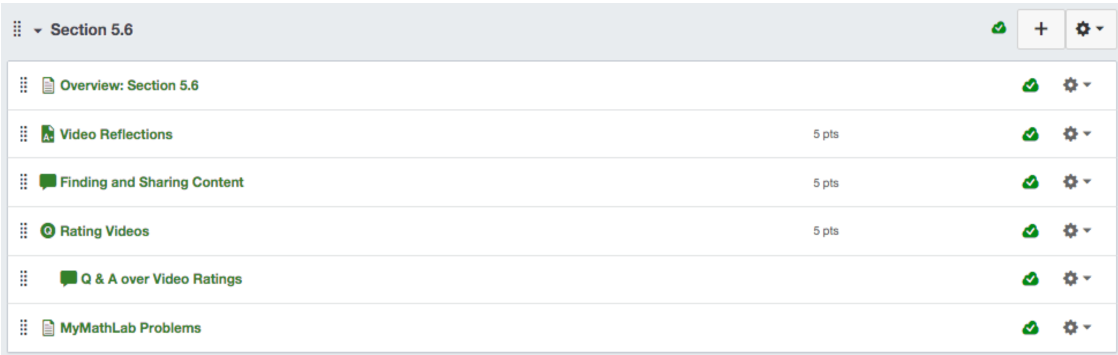

Figure 1. Module Overview of Lesson.

Activities Overview

The purpose of the Activity Overview is to help students understand how to research and review math videos. The objective is that through watching and critiquing the videos, students will gain greater insight and better understanding into adding and subtracting fractions. Because students will not always have the opportunity to have a math instructor teaching them the information, having them determine and communicate what is valuable from will help them become a better consumer of knowledge. These activities include:

- *Video Reflection:* Students will watch a few videos and then compare and contrast the validity and usefulness of the videos.
- *Finding and Sharing Content:* Students will find a video from a given topic in order to share with others.
- *Rating Videos:* Students will watch a few videos and rate the quality of the video and discuss the strengths and weaknesses of these videos.

   - *Q & A over Video Ratings:* Students will have a forum to discuss the videos they just rated with one another, to ask questions and help with conceptual understanding.

- *Problems:* The students will then log into MyMathLab to practice some of the problems learned in section 5.6.

The following are more in-depth descriptions of the activities, their objectives and purpose.

Activity: Video Reflection

Sometimes you need a refresher of a skill or understanding of a concept. In order to figure it out, you go to the internet to find a video. However, there are so many choices out there with different ways of explaining, this process can be quite confusing. In order to help students better prepare for this learning and to improve one-on-one communication with the instructor, they will watch three movies and answer a few questions that will allow the instructor to gauge student conceptual understanding of adding and subtracting fractions.

Video 1 (figure 2) is a refresher video of how to add and subtract fractions, but it does not help a student know what to do when the denominators are different values. Students are given the hypothetical situation that when searching for a video to help them in adding and subtracting fractions with differing denominators they come across videos 2 (figure 3) and 3 (figure 4), and they then must answer the questions below.

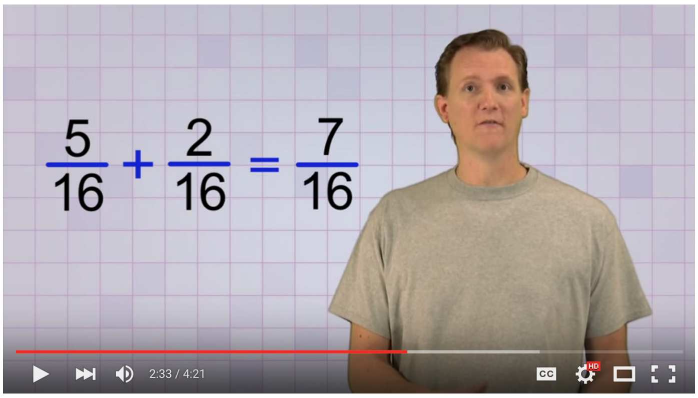

Figure 2. Math Antics – Adding and Subtracting Fractions.

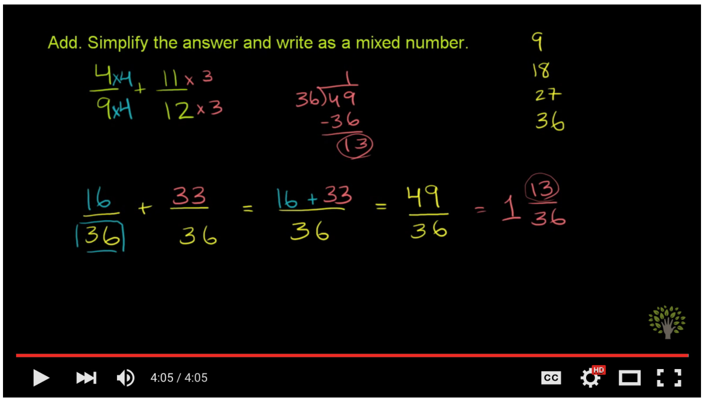

Figure 3. Easy Way To Add and Subtract Fractions.

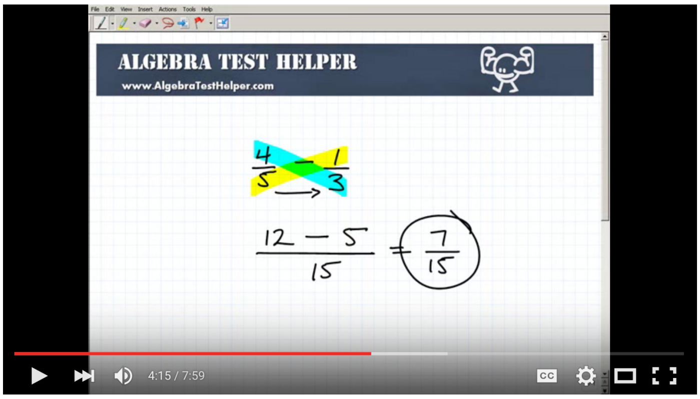

Figure 4. How to Add Fractions That Have Different Denominators.

Students are then prepped with the following prompt and questions to spark reflection on the videos they have just watched and to discuss some of the conceptual understanding:

> "Imagine you are walking in a tourist location and you stumble across a sign that says: 'Shortcut - Get To Your Destination Quicker This Way' - would you take it? Regardless of how you answered that question, if you were able to see a map and learn ***how*** the shortcut would save you time in context with the rest of the trip you could piece together a better understanding of the area. Learning a math concept is much like touring a new destination - the more you understand the big picture the easier it is to get where you want to go.

After watching these three videos please answer the following 2 questions:

1) Why does the Bow Tie Shortcut in Video 3 work? (hint: think about what you are multiplying to the first fraction and what are you multiplying to the second fraction)

2) Is the Bow Tie Shortcut the best choice every time? (hint: what happens when you try to do it with the problem in Video 2)."

This reflection allows for the instructor to see if they are understanding the bigger picture of adding and subtracting fractions or at least the ability of the student to communicate those thoughts. Appropriate feedback and correction can be offered as the instructor sees fit.

Activity: Finding and Sharing Content

The next activity focuses on students finding and sharing video content with each other. Students are told they are given a problem to which they have to add or subtract a fraction (but the fraction contains variables) and you can't quite remember how to do it. One such problem could be the following: . Students are then told to go find a video that helps them explain how to add/subtract this problem. They are encouraged to find a video that they feel comfortable explaining the steps to someone else. This allows for students with differing skills and abilities to share a video that is specific to their current learning.

Next, students will be asked to share their video in the discussion board in the LMS. Then, they will respond to three other videos with one thing you like about the video and one thing you think the video could improve. This helps them communicate some of the ideas and concepts with their peers and provide opportunities for social interaction.

Activity: Rating Videos

In this activity, students are given two videos then are asked to (a) rate the videos and then (b) mention what they view as strengths and weaknesses. Figure 5 and figure 6 demonstrate two such videos that discuss other learning objectives necessary for adding and subtracting fractions. A discussion board allows the students to ask questions regarding the videos and the survey information is collected and then the results are shared with the rest of the class.

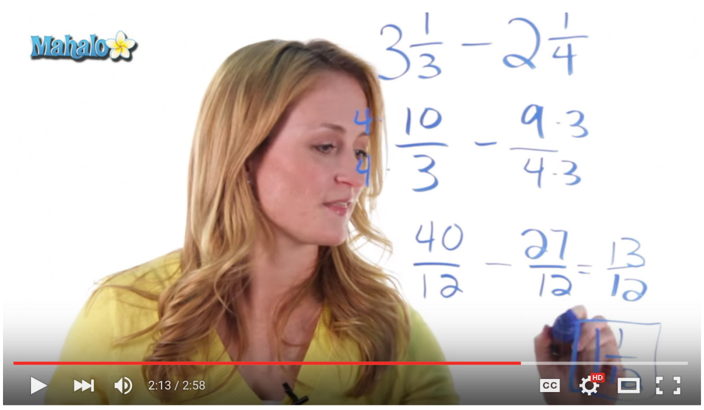

Figure 5. How to Add or Subtract Mixed Numbers.

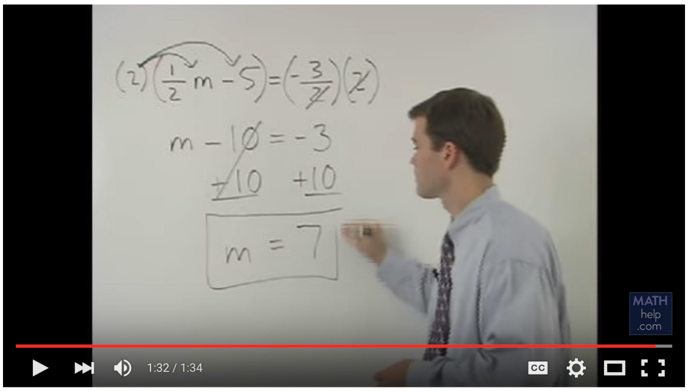

Figure 6. Solving Equations with Fractions.

Activity: MyMathLab Problems

Students will then solve a few problems using the MyMathLab to also show procedural knowledge and verify performance. An instructor can choose how many problems they feel will demonstrate mastery, but it should be noted that with the other social activities the amount of work required should be lowered from a traditional drill and practice style learning environment. Not many problems are necessary to demonstrate a mastery of a concept, and the video viewing has helped with multiple views of the same types of problems.

Students Participation in the Activities

Video Reflections

There are benefits behind student communication and feedback from an instructor to verify conceptual understanding. In the first activity of Video Reflections the students were to reflect upon the videos and submit their personal response that would only be seen by the instructor. The purpose of the activity was to introduce an alternative algorithm and encourage students to start discovering some of the issues that come from seeing multiple ways to solve one problem.

The two questions answered by students allowed the instructor to assess two NCTM processes. First, are students making connections between two videos demonstrating different algorithms? Second, are the student able to communicate when there were moments to implement different algorithms or shortcuts to the instructor? Measuring connections and communication is challenging, if students only perform drill and practice problems in an online environment.

Some of the answers from students on the first question demonstrated a deeper understanding of the subject and ability to make connections as demonstrated by Jenny who stated, “The reason it works because to come up with a least common denominator you have to times the numerator by the other fractions denominator. Whatever you multiply the denominator by to get the LCD you need to do to the numerator and that is why you multiply diagonally." However, another student, Amelia, answered the question by including, "You are cross multiplying the number to get the number you need." This learning activity helps involve the instructor as part of the learning and can help address issues in comprehension with students who are struggling with conceptual knowledge. Amelia is confusing two different concepts and shortcuts, because she is finding memorization strategies (when two fractions are next to each other one must "cross multiply"). These questions are asked without a student needing to feel social pressure of how other students will view their responses, because only the instructor will see these responses and can address them appropriately. The teacher can begin a dialogue of communicating this mathematical concept with students who are struggling like Amelia and reinforce the conceptual knowledge of students like Jenny.

Communication was also taking place in helping students to mathematically prove why one shortcut algorithm worked. A good demonstration of what the instructor should be looking for came from one student, Anna, who stated: "If you used the Bow Tie method on this problem you would be dealing with very large numbers. By multiplying 18 X 24 you would have a denominator of 432. You would have a lot of simplifying to do. For this problem it would be easier to use the common denominator of 72. The Bow Tie method would work but would be harder to use."

Finding and Sharing Content

The expectation desired through the activity is to provide an opportunity for students to communicate their ideas and thoughts with fellow students. Part of the objective is to make them realize that all videos are not created equal (especially when it comes to determining how to solve a problem). Also, by having them view a variety of videos, they will better understand some of procedural knowledge. One such interaction among students and the instructor can be seen in Figure 7.

Rating Videos

This activity was designed for students to give their feedback, and then the data collected can be used to further a discussion on the topic of videos for learning. Figure 3 shows the results of two video ratings performed in the class with the different percentages. One interesting point was that each of these video assignments were from more difficult learning objectives with the last videos analyzing content that had adding and subtracting fractions with different denominators. Therefore, all the content that students needed to meet content outcomes were covered throughout the activities that focused upon learning process standards.

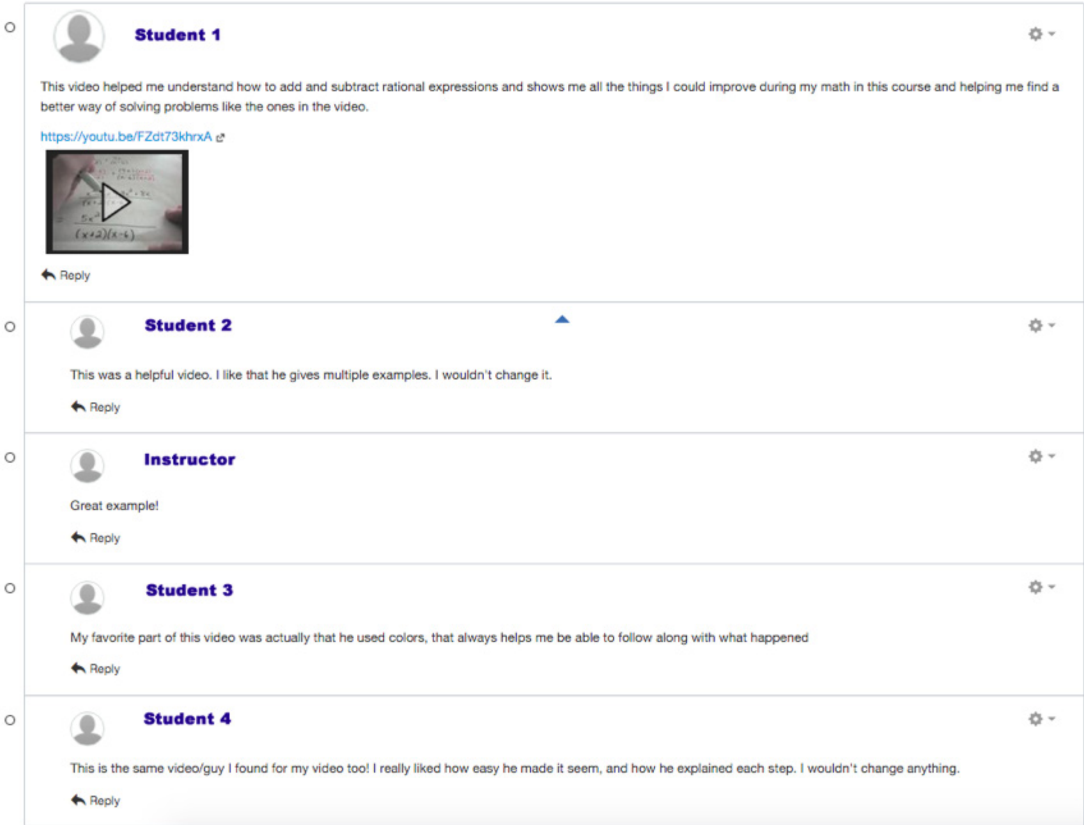

Figure 7. Example of Video Discussion.

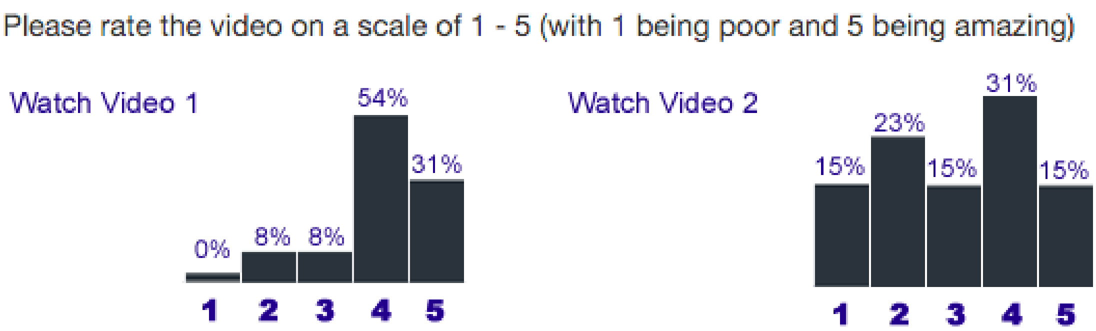

Figure 8. Results of Video Ratings.

Issues with Delivery

There were a few issues that were noticed through the enactment of these online math lessons which will help improve the quality of the lesson in future implementations. First, the completion rate was low among the students in these assignments which could be contributed to a number of factors. One potential factor was student course expectations had already been developed to work individually for more than eight weeks, and so changing assignment expectations that required student behavior changes made participation more challenging. On future implementations of this lesson, it is suggested that the instructor introduce the instruction of process standards earlier in the course and build social interaction opportunities with other such activities at the beginning rather than introducing these activities in the middle of the semester when habits have been formed.

Another issue was that the asynchronous discussion sessions tended to have initial posts without much further discussion. Future implementation of this activity could focus on deepening the clear expectations and rationale through instructions and reminders from the teacher. Alternatively, you could have two to three required sets of feedback staggered over a period to time to allow time for the discussion to unfold in a more authentic manner. As well, this activity could potentially take place synchronously with an emphasis placed upon coming to consensus among the students.

Conclusion

In trying to improve the quality of learning and strategies implemented by math teachers in an online environment, it is important that lesson outcomes focus upon the desired behavior as well as content knowledge and procedural understanding. Implementing activities that encourage social activity of student-student and student-teacher will have the power to help an instructor assess content knowledge of students. In addition, the instruction will be able to measure student communication skills with the instructor and other students to give appropriate feedback as desired.

References

Babson Survey Research Group. (2013). *Changing course: Ten years of tracking online education in the United States.* Babson Park, MA: Allen, I. E., & Seaman, J. Retrieved from http://www.onlinelearningsurvey.com/reports/changingcourse.pdf

Hawkins, A., Barbour, M. K., & Graham, C. R. (2012) 'Everybody is their own island': Teacher disconnection in a virtual school. *International Review of Research in Open and Distance Learning, 13*(2), 123-144.

Murphy, E., & Rodríguez-Manzanares, M. A. (2008) Revisiting transactional distance theory in a context of web-based high-school distance education. *Journal of Distance Education, 22*(2), 1-14.

National Council of Teachers of Mathematics (NCTM). 2000. Principles and Standards for School Mathematics. Reston, Va.: NCTM.

SECTION 2
EDUCATIONAL TECHNOLOGY

Smart City Applications in Turkey

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Introduction

Smart cities are cities that increase people's living standards, make their environment more livable, and also provide economic and social benefits. Today, people migrate to big cities because of better living conditions. As a result, the number of people in big cities is increasing and it is increasing in the density of people per square meter. Along with people, there are many properties such as the number of vehicles and the number of goods are increasing. If this is the case, the cost of the city is increasing. More people create more confusion, require more security, and create more environmental pollution.

Cities are smart in order to overcome these negative situations. With the cities becoming smart, both people will be able to live more comfortably and the city economy will be stronger. The main responsibility of smart city applications in our country is T.C. Ministry of Environment and Urbanism. The municipalities also lead to make the cities smart.

First, municipalities have developed a number of information systems that enable citizens to work directly on the Internet instead of coming to institutions. Some of these services offered in electronic environment are: E-Proposal, Debt Inquiry and E-Payment System, IT Management Information System, Media and Public Relation Information System, Reconstruction Application Information System, Project Management Information System, Nursing Home Information System, Cultural Activities Information System, Audit Information System, Legal Business Information System, Fire Service and Emergency Information System, Disabled Services Information System, Tender Information System, Document Information System, Fixture Management Information System, Advertisement Information System, Request Complaint Form, Pharmacies, Assembly Decisions, Council Decisions.

All of the information systems mentioned above are accessible to citizens via web or mobile platforms. In this way, the density created by the institutions is reduced. In addition, the cities can be watched 7/24 by placing municipal cameras at important points of the city by municipalities. This contributes to the credibility and presence of the city. By entering the websites of the municipalities, city can be viewed.

Institutional Constitution and Legal Legislation

Smart city works in Turkey continues rapidly. In order to make these studies more efficient and effective, T.C. Ministry of Environment and Urbanism, General Directorate of Geographic Information Systems, Department of Smart Cities and Geotechnology, Smart Cities Branch Directorate is founded. Their mission is as follows (https://cbs.csb.gov.tr/birimler/akilli-sehirler-ve-cografi-teknolojiler-dairesi-baskanligi/1565):

1) To develop software related to smart city applications, to carry out policy and strategy studies, to carry out projects, to coordinate and to ensure widespread use,

2) To make the necessary arrangements for establishing city information systems in a standard and common way,

3) To carry out implementation, regulation, development and monitoring activities related to navigation, management, automation and documentation systems that integrate geographic information systems applications,

4) To conduct business and operations related to the operation, maintenance and management of geographical applications developed by the General Directorate,

5) To conduct research, monitoring, indexing and reporting activities related to geographical information technologies and smart cities,

6) To represent our country in the work carried out by national and international institutions and organizations in matters concerning the field of duty, to coordinate cooperation and harmonization activities,

7) To do other work and operations given by the General Manager.

No legislation has been published until the first half of 2018. Work on the subject continues. In the short term, it is expected that the legislation to include policies and strategies will be published.

Municipalities and Smart City Applications

We have municipalities that want to smart their cities as soon as possible in cooperation with major technological organizations. This section presents some of these municipalities and their practices that have been worked or carried out within the municipality.

Adana

Adana (http://create.adana.bel.tr/) is the partner of an international smart city project under H2020. The project “Congestion Reduction in Europe: Advancing Transport Efficiency-CREATE” is an H2020 research development project. While the project’s manager is London, Adana is a partner in the project. Within the scope of the project, economic, social and environmental transport policies and social / economic pressures will be evaluated in 1st step cities Bucharest, Skopje, Amman, Talin and Adana. Solutions have been produced for transportation problems in London, Paris, Vienna, Copenhagen and Berlin. Based on the results of these solutions, a sustainable solution proposal for transportation problems in Adana will be developed.

Ankara

In Ankara (https://www.ankara.bel.tr/), there is a tracking system in the context of smart transportation systems. All buses can be monitored over the internet.

Antalya

Antalya (https://www.antalya.bel.tr/) is an advanced level in our country within the scope of smart cities. Within the scope of manageable internet service, it provides the necessary infrastructure for free Wi-Fi service in more than 30 locations.

Smart lighting and smart irrigation systems were established in Yavuz Özcan Park as pilot project. The smart irrigation system works according to the moisture condition of the soil and when the soil is dry, the irrigation system is active.

City information screens, which will serve citizens and tourists, are also installed in many different locations. With the screens, various benefits will be provided, such as informing the citizens and communicating their problems, and the governance systems of the municipality will be strengthened. It will provide significant convenience for tourists and will be accessible to many points in the city.

Electronic monitoring system is installed in more than 50 locations within the scope of smart transportation and traffic project. This will provide the necessary data base for traffic safety, real smart signaling and smart transportation.

Smart lighting systems that will make a significant contribution to energy consumption of the city are also established in Yavuz Özcan and Serdengeçti Park, which are chosen as pilot regions. In the parks there will be street lights that increase or decrease their light according to the light level of daylight. The system, which can be managed remotely and the light level can be adjusted, will save the city lighting. Central monitoring of defective lamps positions, on / off / off of hourly lamps, follow-up of remaining lamp life, daylight on / off / dimming, on / off / dimming with motion sensor will be included in smart lighting system.

Within the scope of smart health, the following transactions are carried out. Patients with chronic illnesses will be monitored online by the attendant doctors. The sugar, blood pressure and heart rate measurements that will be made in the patients' homes will be controlled by doctors. In case of high values in the measurements, the citizens will contact the patient before they go to the hospital and they will give information about what to do. If the patient feels bad and encounters an urgent situation, 112 emergency services will be reached with the panic button. Any team that sees the patient's previously identified anomalies immediately will be able to determine what kind of intervention is needed.

Bursa

In Bursa (http://akillisehir.bursa.bel.tr/), free, secure and high quality internet service is offered for use in long distance travel buses which are in the service of citizens.

Many inland wireless internet services are provided in line with the internet needs of domestic and foreign guests coming to public service buildings.

The data coming from 20 different vehicle follow-up companies are collected in one center. Metropolitan Municipality has established the infrastructure for the system brought a sense become the first in Turkey to all users instantaneously public transport offers tracking and reporting facilities.

With the application 'Love Chip', it is possible to connect easily with the relatives of Alzheimer's and mentally ill citizens. The patient is carrying to it. In this way, it can monitor instantly from the internet environment 24 hours a day.

Ambulances and Funeral Transport Vehicles, Fuel Tankers, ... etc. A total of 2,175 defined vehicles including Authority vehicles and Excavation vehicles are followed through Vehicle Tracking System.

Enterprises that release wastewater to nature; can be monitored online in real time with the remote wastewater monitoring station instantly. All the values of the amount of water used by the enterprises, the amount discharged to the nature and the pollution parameters of the discharged water can be monitored instantaneously.

Denizli

Denizli (http://akillisehir.denizli.bel.tr/) is an important city at the point of smart cities. Smart City combines with many possibilities and smart solutions are offered to the citizens. These are:

Transportation: Traffic Management System Project, School Services Tracking System, Mass Transportation Control System, Green Wave System, Vehicle Tracking System, Smart Card and Free Wi-Fi Service in Buses, Denizli Kart Smart Spot Points,

Water Management: Scada System, Smart Drip Irrigation System

Information Systems: Geographic Information Systems, Urban Security Management System (MOBESE), Collection of 112 in One Number, e-Signature Project, City Cameras

Environment: Wastewater Treatment System, Energy Production from Biogas

Energy: Our Solar Power Project, Free Internet and Mobile Phone Charging Station

Smart Applications: Transportation Portal, Reading Water Meters Online System, Mobile Site Inspection Project, View / Send Application, Advertisement Mobile Control System, Pocket Parking Management System

İstanbul

In Istanbul (http://isbak.istanbul/), there are advanced information and communication technology applications that support transportation. These applications are Traffic Measuring Systems, Traffic Information Systems, Traffic Signaling Systems, Adaptive Traffic Management System, EDS-Traffic Control Systems, Traffic Control Center, Mobile Applications, Mass Transportation Information Systems and Public Transportation Camera Systems.

In modern tunnel management systems, control of field equipments is done with microprocessor based devices known as PLC. Thanks to the PLC and SCADA system, which plays an active role in the operation of the tunnel, all systems in the tunnel can be remotely monitored and controlled if necessary. Taking into consideration the fault conditions in the design of tunnel automations, it has been adopted that the technological precautions should be taken in order to prevent the faulty tunnel process.

With Fleet Management Systems, it is aimed to direct and control the vehicles and vehicle drivers in the best way. With the system, it is ensured that vehicles that serve your institution are monitored on-line, their speeds are controlled, where and how much they are paused and what paths they follow. The system works with the logic of transferring the data received from GPS satellites connected to the vehicles to the server computers via GSM / GPRS.

It is an automatic meteorology surveillance, analysis and anti-ice system installed on roads to avoid traffic accidents caused by hidden ice in tunnel entrances, exits, bridges, viaducts and roads so that the city life is not affected by icing detection and prevention system in winter months. With this system, it is guaranteed that the water formed on the road will remain as a liquid without freezing, and precautions can be taken in areas where there is risk of icing.

Smart Parking Management System is an integrated parking management system that contributes to the country's economy by aiming to reduce carbon emissions by providing profit from fuel by time with smart systems for the use of high quality, efficient and environmentally friendly parking lots. Equipment and system solutions are offered in parking lots in order to speed up the transition safely and to save time with smart systems.

İzmir

621 thousand meters of fiber optic cable has been laid in Izmir (http://www.izmir.bel.tr/) within the scope of, "İzmirNet Project" and "Smart Traffic System". This situation has created a very important infrastructure in İzmir's smart city target.

The camera monitoring system, the wireless 3G data connection system and the passenger counting system are installed in 1500 buses. Priority system was established at 164 junctions of fire brigade.

All of the parking lots have been made "smart". With this system, how much space is available in the parking lots can be reached from internet or led screen. You also have the chance to learn how to navigate to the nearest car park using navigation on the mobile site.

"Traffic Mnitoring Camera" at 110 points, "Meteorology Measurement System" at 30 points and "Gabari Measurement System" at 16 points were established. In order to create traffic density information, 209 "Traffic Metering Sensors" and 48 "Variable Message Systems" (DMS) and 60 Parking Information Screens have been activated to transmit this information and other traffic information to the drivers. The system is managed by approximately 5,000 cameras and 10 thousand smart phones.

Observing and controlling rule violations, reducing emission rates, and reducing fuel and spare parts expenditures are among the advantages of the "Smart Traffic System". The system provides a safer vehicle and pedestrian traffic as well as high efficiency of road capacities. The shortening of travel times, the accumulation of junctions and the reduction of waiting times are the most important consequences of the system.

Kars

In Kars (http://www.kars.gov.tr/akilli-kent-kars), the applications that can be taken into consideration in the context of Smart Cities are:

- Smart City management center to monitor and manage Smart City applications

- Free Wi-Fi Internet service in the parks (Mesut Yılmaz Park, Ataturk Tea Garden, Harakanı Tomb)

- City Access Points / Information Points (Kiosks)

- Smart Junction, Smart Stop and Smart Lighting applications at various locations in the city

- Sarikamis Ski Center Transit System

- BuluTT Eye (recording of high-resolution images for security to Turk Telekom data center)

- History, culture, tourism etc. related to science through smart phones. information can be reached “Kars Mobil” application

- Application of the Voice Steps Project to the courthouse and the hospital building after the governorship of Kars

- “Barrier-free SMS” application for better service to disabled citizens

- Regular informing of Kars air quality with meteorological measurement, heat and snow thickness

It is aimed to modernize the communication infrastructure of Kars province center, to increase the fiber ratio in Kars province center to 100%, to increase the speed provided to the customers in the province center from 12 Mbit to 50 Mbit and to benefit from the services of TIVİBU by all the customers in the province center within the scope of Kars Fiberkent Transformation.

The Voice Steps application for the Kars Governorate building, which was developed for the first time in the world, provides voice guidance service through the smartphones in places where they have visually impaired.

Kayseri

Kayseri (https://www.smartcitykayseri.com/) is a very conscious city within the scope of smart cities. While most of the projects listed below are in use in the city, others are still in the works.

Within Smart Environment, Smart Lighting, Solid Waste Energy Management, Sustainable Energy Action Plan, Smart Irrigation, Air Quality Stations.

Within the scope of smart community, Navigation Implementation for the Disabled, Charge Units for the Disabled, City Square Energy Pipeline, Smart Library Construction, Informative Kiosk, Sms System Installation (For City Visitors), City Guide Application.

Within the scope of smart transportation, Smart Station, Rail Control Center, Bike Road and Station, Transportation Application, Smart Junction, Ambulance

Transit Elevation, Autonomous Bulk, Transportation Vehicle, Electric Bus, Fleet Tracking and Management for Municipal Vehicles, Smart Parking.

Within the scope of smart life, Wi-Fi Points, Sports Centers, Erciyes Ski Center Live Cameras.

Within the scope of smart management, Smart City Management Platform, Business Processes and Document Management System.

Sakarya

In Sakarya (http://www.sakarya.bel.tr/), every step of drinking is followed by the Scada system, which is developed for continuous monitoring of the city's drinking water 24 hours a day. The problem experienced at any point of the drinking water network can be seen instantly and can be intervened immediately. By connecting to the Scada system, it is possible to instantly control the purification facilities, drinking water elevation centers, water depots, many mechanical equipment on the field and the level of Sapanca Lake in many points of Sakarya via internet.

Within the scope of smart transportation systems, there is a tracking system in the busses. All buses can be monitored over the internet.

Discussion and Conclusions

It is seen that most of the municipalities working on smart cities are primarily oriented to smart transportation systems. As a result of detailed reviews and literature review, Smart City Applications are divided into 8 headings. These; Smart Transportation, Smart Environment, Smart Health, Smart Life, Smart Governance, Smart Industry, Smart Economy and Smart Security. Only one system or one space is not enough for a city to be a smart city. In order for a city to be an smart city, it must contain all necessary systems and communicate with each other in these systems. It is expected that the road data obtained by the Smart Weather System will be sent as information to the drivers in the Smart Transportation system and recommend the road route if necessary. In addition, it is expected that meaningful estimations will be made for the future through the relationships between the data, by collecting all systems at a single center. With so many solutions in place now, our country may face the danger of being a technology garbage disposal. Because, in the current situation, there are many smart systems but a system that is not familiar with each other. Immediately, smart city applications should be framed by a legal legislation and our country should not be allowed to have a technology repository.

As you can see, many municipalities carry out smart city studies in their own fields with institutional collaborations. The municipalities carry out these transactions in agreement with different companies. These applications are realized in smart cities with wired or wireless technologies. Before implementing smart systems, it is necessary to have comprehensive forward-looking road plans and act accordingly. The smart system, which is a stand-alone solution, will lose its effectiveness and efficiency after a certain period of time if it cannot communicate with other systems.

References

Department of Smart Cities and Geotechnology, https://cbs.csb.gov.tr/birimler/akilli-sehirler-ve-cografi-teknolojiler-dairesi-baskanligi/1565

Congestion Reduction in Europe: Advancing Transport Efficiency-CREATE, http://create.adana.bel.tr/

Ankara Metropolitan Municipality, https://www.ankara.bel.tr/

Antalya Metropolitan Municipality, https://www.antalya.bel.tr/

Bursa Metropolitan Municipality, http://akillisehir.bursa.bel.tr/

Denizli Metropolitan Municipality, http://akillisehir.denizli.bel.tr/

İstanbul Informatics and Smart City Technologies, http://isbak.istanbul/

İzmir Metropolitan Municipality, http://www.izmir.bel.tr/

Kars Governorship, http://www.kars.gov.tr/akilli-kent-kars

Sakarya Metropolitan Municipality, http://www.sakarya.bel.tr/

Smart City Kayseri, https://www.smartcitykayseri.com/

Educational Technology in Classroom: A Cross Country Comparasion

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Introduction

The education landscape has changed drastically in the last 10 years. Schools and colleges are eager to implement strategies that incorporate technologies in the classroom (Power, 2014). More and more educational institutions and teachers are implementing technology in the classroom in a multitude of different ways in an effort to increase student engagement and retention of knowledge. In a recent survey, three-fourths of U.S. K12 teachers indicated that they use technology in their classroom to help motivate their students (Luckerson, 2014). This movement to implement technology in the classroom is driven by results. The use of instructional technology in the classroom enhances learning and actually makes learning fun for students, which in turn motivates them to want to learn more (Eyyam & Yaratan. 2014).

The use of iPads and Interactive Whiteboards enables students to relate what they learn in the classroom with the world in which they exists. Though some educators and institutions are reluctant in embracing these technologies, change is inevitable. Technology is significant in every aspect of life, and student learning is no exception. Technology in the classroom changes how teachers and students communicate with each other. Today's schools are privileged to have an opportunity to integrate technologies during the learning process. The iPad and Interactive Whiteboard technology opens up a classroom to the world enhancing personalized learning (Silton, 2015).

The iPad has the capability of downloading over 5000 educational applications and over 1000 can be downloaded for free to enhance learning (Donohue, 2015). Studies show that students who use iPads perform better than those who do not use iPads. Although massive adoption of the iPad has presented challenges in curriculum control in the United States, many schools prefer to use these devices since they are highly portable, convenient, less likely of being hacked, and cannot be reprogrammed (McConatha & Penny, 2014). In a more recent study, students chose the iPad as the most favored learning tool used in the classroom, helping to keep them focused and on task (Mango, 2015). Teachers who incorporate the iPad in classroom learning tend to practice Project Based Learning (PBL) which prepares students for problem solving and project building activities (Maich & Hall, 2016).

The main functions of these two technologies are to improve collaboration inside and outside the classroom, provide opportunities for learners to be able to work and succeed at their own pace, prepare for future careers, and enhance student / teacher engagement (Donohue, 2015). The United States and Turkey have been able to improve their performances, create instructional flexibility, and achieve resource efficiency through the use of Interactive WhiteBoard and iPad technology (Silton, 2015).

The aim of this study is to compare the educational technology used in the two countries and discuss people's point of view and use of technology. United States and Turkey have different technology infrastructure therefore people's attitude towards technology differs. This research highlights several discrepancy between the two countries and technologies. At the end of the study recommendations are summarized for education decision makers.

Literature Review

Educational Technology Implementation in US

The iPod Touch was first introduced in 2007, while the use of iPads in the United States emerged in 2008. The education sector has been slow in adapting to this technology. In addition to assisting in learning, the iPad has increased peer interaction by connecting students with other students, including students with disabilities (An, Alon, & Fuentes, 2015).

Ipad In Classroom

The iPad has vast benefits in the US in education because it enhances collaborative learning and makes the learning experience personal. It enables intellectual brainstorming via the Internet allowing access to a vast world of knowledge. The iPad contributes towards monitoring and assessment in a number of ways. The iPad provides a platform where learners can switch from formal to informal learning. Students can do further reading even when they are out of the classroom, therefore, enabling students to interact more on the topic. It makes learning interesting, and students can also make notes on the same subject at home (Keengwe, 2013).

The iPad keeps students active during the lecture and while at home. The technology helps students to communicate face-face with others contrary to the use of laptops, desktops, and netbooks while computing with a mouse driven screen. In addition, students, while traveling, can engage themselves freely with other things while they learn. Learning is not affected by the environment since ipads can take place in and out of the classroom (Pegrum, 2014).

The use of iPads in the United States allows students to contribute in intellectual debates thus enhancing learning. Students can participate in online groups to share knowledge. Such discussions aid students in solving problems. Students are able to voice opinions in discussion forums and support them with experimental evidence (Maddux, 2012).

Although iPads may be perceived as being expensive its benefits are remarkable. The iPad's popularity is proven by the attitude of students towards the iPad and its use in the United States. The iPad can be used to teach most subjects especially those that do not require a lot of hands-on instruction, like a lab. Instructors use the iPad to teach and assign homework to learners. The teachers also provide solutions to these assignments, which may include brainstorming and presentations, so that students can ask questions on issues that are not clear during the lesson. The use of iPads also helps teachers to interact and share on the best strategies for improving students' performances. Teachers borrow information about education from other parts of the world, thus they are able to stay abreast with the current trends (Silton, 2015).

Students in the United States have expressed gratitude on the introduction of iPads that replace pens, papers, and books. The students show their preference for iPads in areas such as doing online research, sharing ideas with peers and teachers, and also playing educational games. The use of iPads has improved the quality of education in the United States by making learning a flexible process where learners can learn without face to face contact with the teacher. The use of iPads encourages a learner-centered approach to learning (Kim, 2010).

The understanding of content is essential in education. The goals of education are achieved once students understand and are able to apply what they have been taught. The iPad in the United States educational sector has created confidence among students. It has enabled learners to handle more challenging tasks thus simplifying the learning process. The device has helped learners to gain knowledge in thought-provoking subjects such as mathematics, sciences, foreign languages, astronomy, and history. The use of iPads has facilitated the interaction of various educational disciplines making it easy to freely exchange ideas. Networking of educational professionals has resulted in several reforms in the United States educational sector (Keengwe, 2013).

The use of iPads not only supports learning, but also provides storage for students' work. Students can use stored information as a source of reference for the future. The iPad is also used by students to store personal information such as registration numbers, timetables, course studies, and examination dates. Though the storage capacity of the iPad may be limited, compared to a laptop, the student is able to access the cloud-based storage data. Instructors are able to monitor the student's performance, provide feedback, as well as, share assessments and grades of the students. In addition, teachers are able to communicate with parents concerning students' grades helping to eliminate incidences where some students may hide grades.

Instructors also alert students about assignments given and submission dates. Students in the United States can use iPads to take tests in science and mathematics and gain immediate feedback. The iPad offers teachers a platform for assessing students. Alternately, the students give feedback to instructors about the reasons for performing either poorly or fairly (Maddux, 2012). Learning institutions in the United States have embraced the use of iPads to monitor the progress of their students. Digital portfolios are put in place to keep a record of students' performances from one level of learning to another. Also teachers maintain a student roll to monitor class attendance (Pegrum, 2014).

The United States has managed to improve school management through the use of iPads. School principals are able to monitor the performance of teachers and non-teaching staff. For example, a school principal can keep track of those teachers who are currently in classes, and those who have not attended their respective lessons or left school (Silton, 2015).

The iPad makes studies more appealing to special needs students, by making learning more appealing. Some students lag behind during the lesson, but that does not mean that they are incapable of learning. The use of iPads can help students with special needs by applying applications that support individual learners. With the assistance of this technology, students can excel in studies despite being slow learners. Students can interact with materials provided by the teacher. The student can also ask the teacher questions regarding the topic using the same device. On the other hand, the teacher is able to monitor students and assess student progress. In a case of a student who has reading difficulties, free applications are available that support text- to- speech (An et al. 2015).

Even though the use of iPads has brought a revolution in the education sector in the United States, students can waste time using the iPad doing other things that are not related to studies: such as playing games during class time (Maddux, 2012). Also the iPad has competition from other forms of technology such as laptops. The iPad has a lower capability than that of the laptop, yet the iPad is preferred by students in the United States due to it size and portability (Silton, 2005). In the United States the iPad presents challenges three of which include distraction, too many applications, and easy access to different websites.

Educational Technology Implementation in Turkey

In Turkey technology was introduced in the early 21st century in universities and was transmitted via optic cables. The technology provided auditory and visual communication to learners in remote places. Despite rapid development and commitment of funds in the educational system, the educational system could not meet all expectations (Ekici and Yılmaz, 2013).

National development plans in Turkey emphasized the need to introduce new learning resources. The Ministry of Education in Turkey aims training leaders in educational technology, production of education materials, providing instructional films, materials and equipment in mathematics and science laboratories. Similar to the United States, the administration was charged with the responsibility of providing personal computers, hardware, and software to schools, and establishing a unit for recording and copying instructional materials. Similar to the projects implemented in many developing countries, Turkey has also started piloting its government supported technology integration project-FATIH ("Movement of Enhancing Opportunities and Improving Technology", abbreviated as FATIH Project) in 2012 at 52 public schools (4 elementary, 48 high school) and planned to extend the project to all public schools in next few years (Pamuk et al., 2013). But some research pointed out that FATIH Project has not been designed within the Project Cycle Management framework and in its present form, the FATIH Project cannot be integrated into the education system (Ekici and Yılmaz, 2013).

The use of technology by teachers in Turkey mirrored the lack of training provided to the teachers in information technology. Currently, tablets are not used widely. Also teachers lack training in the use of technology, a fact that inhibits them from adopting it (Çoklar and Tercan, 2014). Türel (2012) stated that teachers avoided use of IWBs during their lectures. Results of the research also indicated that teachers experienced a lack of technical skills, pedagogical knowledge, and lack of materials regarding the effective use of IWB (Türel, 2012). Turkey lacks good policies to support the implementation of technology in schools. The policies are designed to support initiatives, and without appropriate policies sound implementation of technology cannot be achieved. Dağhan et al. stated that the most important problem related to the use of these technologies seems to be caused by lack of sufficient educational e-content (Dağhan et al., 2015). Students in Turkey are not encouraged to focus on design and evaluation of products (Pamuk, 2012).

In 2013, Pamuk et al. investigated whether or not Interactive White Boards and Tablet Computers distributed to teachers and students in the pilot schools were used and the effectiveness of those Technologies in teaching and learning, also the problems and issues emerged with regard to use of IB and Tablet computers. The results revealed that although there is a promising use of IWB, there is limited, in some cases no, use of Tablet computers. Both teachers and students were in favor of IWBs, but were also skeptical about Tablet computers (Pamuk et al., 2013).

Interactive Boards in Classroom

Interactive Whiteboards come with benefits. For example, once the work is done it can be retrieved back for future reference (Matthews, 2009). The ability to retrieve information affords a stress-free environment for students, by allowing students to refer to lessons even in and out of the classroom. Kopp (2013) maintains that Interactive Whiteboards assist students in understanding concepts and broadens the minds of the students.

Interactive Whiteboards have played a great role in transforming chalkboard into an electronic board. It has broadened the mind of students as they deliberate on subjects through demonstrations. Additionally, Interactive Whiteboards foster more understanding as the teachers bring the Internet experience into the classroom. A projector and a screen are used to display information (Betcher & Lee, 2009). The IWB enables teachers to present using different learning styles, making learning engaging and fun for the student (Idal & Casey, 2014).

The IWB enables teachers to use the resources from the Internet. Using the IWB, students are able to interact with a small class, thereby enhancing their understanding. With the Interactive Whiteboard, teachers can bring more examples to reality. To create more understanding, teachers derive more examples from the web thus making the class more interactive. This technology enables teachers to use multimedia materials that enables educators in Turkey to present and explain concepts (Idal & Casey, 2014).

According to Idal and Casey (2014) in the teaching profession, teachers are expected to enhance collaborative learning with their students. With the IWB, teachers track students step by step in their studies as knowledge is shared in the classroom. Teachers engage students with challenging questions and simultaneously providing answers to students. Teachers engage students in peer-to-peer discussions making it part of the classroom studies (Pegrum, 2014).

Teaching requires educators to repeat concepts and ideas that have been taught. In the educational field, teachers are required to teach using repetition reteaching the same concepts taught to previous students, as well as, those who will follow. With the Interactive Whiteboard, teachers can save the notes for future reference (Thomas & Schmid, 2010). They can also refer to the notes while making revisions for the students they will have in the future.

Schools that have adopted the technology of the Interactive Whiteboard help teachers to reconsider their approach to the lesson. This is because the flexibility and the scope for creative learning is enormous, thus, with the aid of the IWB teachers can be flexible, unlike the traditional approach where the chalkboard was the only technology in the classroom. Currently, teachers have a variety of choices of approaches to present lessons, and this makes the class even more stimulating (Camberwell, 2009).

The Interactive Whiteboard motivates students to participate in the class by interacting with the materials on the IWB. As students participate, teachers can assess the level of understanding of students concerning the topic being discussed (Betcher & Lee, 2009). This enhances indepth reading where the student's mind becomes involved in critical thinking. Additional learning for students takes place through observation and discussion Therefore, students are encouraged to participate, allowed to comment, and invited to interact with the materials. This aids teachers to provide clarity and repeat challenging concepts being taught in the class while using this technology (Littleton, et, al., 2007).

Another benefit of the IWB comes during a learning activity where students can engage more in encoding and decoding. This process promotes critical thinking. When students engage in mind activities, they develop more intellectually. It is during enhanced brainstorming sessions where students participate fully in discussions. Further, the student's capacity for understanding is increased by this interactive session (Paris, 2011).

The IWB provides an avenue where students can observe what teachers are trying to say. As students interact with this technology, world phenomenon becomes efficiently depicted in their mind. When this process is repeated, students tend to develop a consistent pattern of identifying symbols and signs as they interact with them in day to day living (Baguley & Danaher, 2014).

The challenge with Interactive Whiteboards is due to students only have access to the technology in the classroom. Learners in the United States can go wherever they want with their iPads, a technology similar to the IWB. Students using iPads still need Interactive Whiteboards to share ideas with fellow learners in a classroom. Voogt and Knezek (2008) argues that the Interactive Whiteboard allows students to engage in discussions, sharing ideas like brainstorming. Consecutively, by engaging students in class work the results are a personalisation of information by online scholars. The learners are motivated, and thus the session becomes more engaging. Also, students can discuss among themselves, thereby enhancing coherence and harmony in the classroom (Rief & Heimburge, 2007).

Technical support is needed when using Interactive Whiteboard technology in Turkey. It facilitates learning by addressing problems that may occur during the learning process. Teachers are also involved in IWB training, receiving instruction that allows them to facilitate the lesson without problems. Technical difficulties with the IWB may occur in the class as a result of a stylus defect or overuse. A stylus is an essential tool for the IWB to operate. They need to be checked regularly. Another technical difficulty may be a poor projector or Internet connection hindering the smooth use of the IWB (Matthews, 2009).

Conclusion

The iPad enables each student to share his or her work using the Interactive Whiteboard. It is cost efficient since no connection cables are required. The iPad enhances communication effectiveness. When homes and schools have iPads, it becomes possible for a smooth flow of information between parents, teachers, and students. This keeps students in touch with parents and similarly, teachers are connected to parents. Teachers and students also engage in regular interaction as they deal with the class studies. Students can also consult teachers concerning any difficulty with the assignments or the topics at hand. It is noteworthy to state that it is possible for parents, teachers, and students to communicate anytime, anyplace and under any circumstances. This is made possible by just a click of a button. Parents can also be informed about important programs in school such parent meetings. Further, research shows that both parents and students in the United States believe that iPads have contributed greatly by improving the quality of education in and out of the classroom. Although Interactive Whiteboards cannot be compared to iPads, they make the class more appealing and interactive, since teachers and students can use different styles during a presentation (Rau, 2011). Use of technology in the United States and in Turkey has brought significant improvements in the education sector in both countries (Macmillan, 2010).

The introduction of the iPad and the Interactive Whiteboard technology in the United States and in Turkish schools has contributed to the efficiency in the education sector. The use of the iPad and the IWB technology have some benefits to teachers and students. The use of this technology in the classroom motivates and boosts students' understanding. This technology facilitates collaboration in the classroom, improves performance, and encourages interaction among learners. On the other hand, educators can enhance teaching skills, evaluate the progress of students, and give and receive assignments. The primary functions of these technologies are to improve collaboration inside and outside the classroom, provide opportunities for learners to be able to work and succeed at an individual pace, prepare for future careers, and enhance the learning experience. Adoption of the Interactive Whiteboard technology in Turkey has faced several challenges, such as, lack of qualified teachers trained in the technology or internet infrasctructure problems in several areas. . Interactive Whiteboards cannot be compared to iPads because they are not portable and lack privacy. Turkey should continue to increase its technological infrastructure especially in rural areas, and train teachers to fully adopt the use of technology in learning.

References

An, H., Alon, S., & Fuentes, D. (2015). *Tablets In K-12 Education: Integrated Experiences And Implications.* Hershey, PA: Information Science Reference.

Baguley, M., & Danaher, P. A. (2014). *Educational Learning And Development: Building And Enhancing Capacity*. Houndmills: Palgrave Macmillan.

Betcher, C., & Lee, M. (2009). *The Interactive Whiteboard Revolution: Teaching With Iwbs.* Camberwell, Vic: ACER Press.

Camberwell, V., & Lewis, G. (2009). *Bringing Technology Into The Classroom*. Oxford: Oxford University Press.

Çoklar, A. N., & Tercan, İ. (2014). Opinions Of Teachers Toward The Use Of Smart Boards. *Elementary Education Online,* 13(1), 48-61.

Dağhan, G., Kibar, P. N., Akkoyunlu, B., & Baskan, G. A. (2015). Öğretmen ve Yöneticilerin Etkileşimli Tahta ve Tablet Bilgisayar Kullanımına Yönelik Yaklaşımları ve Görüşleri. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 6(3), 399-417.

Donohue, C. (2015). *Technology And Digital Media In The Early Years: Tools For Teaching And Learning*. Washington, DC: Routledge.

Ekici, S., & Yılmaz, B. (2013). FATİH Projesi Üzerine Bir Değerlendirme. *Türk Kütüphaneciliği*, 27(2), 317-339.

Eyyam, R., & Yaratan, H. S. (2014). Impact Of Use Of Technology In Mathematics Lessons On Student Achievement And Attitudes. *Social Behavior And Personality: An International Journal*, 42(1), 31S-42S.

Idal, D., & Casey, M. (2014). Next Practice: Executive Guide For Education Decision Makers.

Lanham, MD: Rowman & Littlefield Education.

Keengwe, J. (2013). *Pedagogical Applications And Social Effects Of Mobile Technology Integration*. Hershey, PA: Information Science Reference.

Kim, T. (2010). *Signal Processing And Multimedia: International Conference*. SIP And Mulgrab 2010, Held As Part Of The Future Generation Information Technology Conference, FGIT 2010, Jeju Island, Korea, December 13-15, 2010: proceedings. Berlin: SpringerLink.

Kopp, K. (2013). *Using Interactive Whiteboards In The Classroom*. Huntington Beach, CA: Shell Education.

Littleton, K., Twiner, A., Gillen, J., Kleine-Staarman, J., & Mercer, N. (2007). *Orchestration With The Interactive Whiteboard*. In: Developing Potentials for Learning 12th Biennial Conference for Research on Learning and Instruction, University of Budapest.

Luckerson, V. (2014). Watch How Word Of Ebola Exploded in America. *Time*, October, 7.

Macmillan, Thomas, M. (2010). *Task-Based Language Learning And Teaching With Technology.* London: Continuum.

Maddux, C. (2012). *Research Highlights In Technology And Teacher Education 2012*. Chesapeake, VA: Society for Information Technology and Teacher Education.

Maich, K., & Hall, C. (2016). Implementing Ipads In The Inclusive Classroom Setting. *Intervention in School and Clinic*, 51(3), 145-150.

Mango, O. (2015). Ipad Use And Student Engagement In The Classroom. *TOJET: The Turkish Online Journal of Educational Technology*, 14(1).

Matthews, J. (2009). *Interactive Whiteboards.* Ann Arbor, Mich: Cherry Lake Pub.

McConatha, D., & Penny, C. (2014). *Mobile Pedagogy And Perspectives On Teaching And Learning*. Hershey, PA: Information Science Reference.

Pamuk, S., Çakır, R., Ergun, M., Yılmaz, H. B., & Ayas, C. (2013). Öğretmen Ve Öğrenci Bakış Açısıyla Tablet PC Ve Etkileşimli Tahta Kullanımı: FATİH Projesi Değerlendirmesi.

Paris, S. (2011). *Interactive Whiteboards Made Easy*. 30 Activities To Engage All Learners Level 6 (SMARTBoard Version). Huntington Beach: Shell Education.

Pegrum, M. (2014). *Mobile Learning: Languages, Literacies And Cultures*. New York: Palgrave Macmillan.

Power, T. (2014). Educational Technology: Evidence Of Impacts On Teaching And Learning. *Findings and recommendations from the DFID Topic Guide on Educational Technology*, 2014.

Rau, P. L. (2011). Internationalization, Design And Global Development : 4th International Conference, IDGD 2011, Held As Part Of HCI International 2011, Orlando, FL, USA, July 9-14, 2011: Proceedings. Berlin: Springerlink.

Silton, N. R. (2015). *Recent Advances In Assistive Technologies To Support Children With Developmental Disorders*. Hershey, PA: Medical Information Science Reference.

Thomas, M., & Schmid, E. C. (2010). *Interactive Whiteboards For Education: Theory, Research And Practice*. Hershey, PA: Information Science Reference.

Türel, Y. K. (2012). Teachers' Negative Attitudes towards Interactive Whiteboard Use: Needs and Problems. *Ilkogretim Online*, 11(2).

Voogt, J., & Knezek, G. A. (2008). *International Handbook Of Information Technology In Primary And Secondary Education*. New York: Springer.

STEM Integrations and Teachers' Role in This Process

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What is STEM?

Living fulfilling and meaningful lives in the 21st century requires individuals to have capabilities such as deep, useable knowledge of scientific and engineering ideas and scientific and engineering practices, as well as the creative, problem solving, and communication skills and judgment to apply STEM ideas (Krajcik & Delen, 2017). It is clear that there is a shift in the way science education is being conceptualized, and such integration of STEM disciplines at the K-12 level offers students an opportunity to experience learning in a real-world, multidisciplinary context (Dare, Ellis & Roehrig, 2018).

In short, STEM is accrued knowledge of science, technology, engineering and mathematics as separate but related fields. However, there are many definitions of STEM. For example, Tsupros, Kohler and Hallinen (2009) define STEM as "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons in contexts that make connections between school, community, work, and the global enterprise" (p. 2). Moore, Johnson and Peters-Burton (2015) define STEM as "the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies" (p.24). According to Krajcik and Delen (2017), a richer, more productive manner of thinking is to define STEM as an integration of science, technology, engineering and mathematics to focus on solving pressing individual and societal problems. Kelley and Knowles (2016) on the other hand, state that there is a need for a conceptual framework beyond a simple definition of STEM education. They explain STEM education as a process approach or a process philosophy involving two or more STEM disciplines, including engineering and mathematical thinking, where the engineering design process is used to solve real-life problems with scientific inquiry (Kelley & Knowles, 2016). Bybee (2013), whose definition was adopted for this study, leaves STEM ill-defined and suggests that the most accurate definition may come from one's personal context and needs and explains the perspectives of nine different STEM education through visual presentations.

STEM Integration

Teaching STEM disciplines through integration is appropriate with STEM purposes.

Wang (2012) reviewed the literature and pointed out that integrated curriculum, with its ability to incorporate information from different fields, has been shown to increase students' involvement, motivation, problem-solving skills, and cooperative learning skills. The "Integrated STEM Education" framework was presented in 2014 by the National Academy of Engineering and the National Research Council. Integrated STEM education provides authentic contexts for learning and enables students to make connections among the STEM disciplines, and it also supports "building knowledge and skill both within the disciplines and across the disciplines" (NAE & NRC, 2014, p. 5). Objectives of integrated STEM education;

- STEM literacy
- 21st century competencies
- Preparing for work in STEM areas
- Stimulation of students in STEM disciplines and providing links.

According to the committee, the results of integrated STEM Education are;

- Learning and success
- 21st century competencies
- Better understanding of STEM content
- Increase pedagogical content knowledge and STEM content knowledge
- The development of STEM identity
- The development of the ability to make connections between STEM disciplines.

Researchers have conceptualized and presented perspectives on what they think integrated STEM is. Honey, Pearson and Schweingruber (2014) provide a basic definition of integration as "working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines" (p. 52). Integrated STEM has been described as integrating science, technology, engineering, and mathematics concepts in ways that reflect the practice of STEM professionals to encourage students to pursue STEM professions (Breiner, Harkness, Johnson, & Kohler, 2012).

A more comprehensive perspective on STEM integration is featured in work of Vasquez, Sneider and Comer (2013), where different forms of boundary crossing are displayed along a continuum of increasing levels of integration, with progression along the continuum involving greater interconnection and interdependence among the disciplines. According to Vasquez et al. (2013), there are four levels of integration. In disciplinary integration, students learn concepts and skills separately in each discipline. In multidisciplinary integration, students learn concepts and skills separately in each discipline but within a common theme. In interdisciplinary integration, students learn concepts and skills from two or more disciplines that are tightly linked so as to deepen knowledge and skills. Finally, in transdisciplinary integration, by undertaking real-world problems or projects, students apply knowledge and skills from two or more disciplines and help to shape the learning experience (Vasquez et al., 2013).

On the other hand, Moore et al. (2014)'s STEM integration framework includes six major tenets for successful STEM education: (1) a motivating and engaging context, (2) the inclusion of mathematics and/or science content, (3) student-centered pedagogies, (4) an engineering design, (5) an emphasis on teamwork and communication, and (6) learning from failure through redesign. Roehrig, Wang, Moore and Park (2012) define STEM integration as the "merging of the disciplines of science, technology, engineering, and mathematics in order to help teachers to: (1) deepen student understanding of STEM disciplines by contextualizing concepts, (2) broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts, and (3) increase student interest in STEM disciplines to expand pathways for helping STEM fields" (p.35).

Bybee (2013) offers a range of models to describe STEM education from various educational perspectives, ranging from STEM as a replacement acronym for science or mathematics to STEM as representing true integration across all four fields. Bybee presents eight approaches for integration with a focus on STEM education. In these approaches, STEM refers to (a) science (or mathematics); (b) both science and mathematics; (c) science and the incorporation of technology, engineering, or mathematics; (d) a quartet of separate disciplines of science, mathematics, engineering, and technology; (e) science and mathematics that are connected by a technology or engineering program; (f) coordination across disciplines; (g) combining two or three disciplines; (h) complementary overlapping across disciplines; (i) a transdisciplinary course or program. He also argues that integration cannot be accomplished quickly and requires development of a plan of action to improve STEM education. Bybee demonstrates that this integration can be done in different ways as STEM 1.0 (single discipline), STEM 2.0 (two disciplines), STEM 3.0 (three disciplines) and STEM 4.0 (four disciplines) in creating the STEM curriculum. He states that these integrations can be done in five different ways such as coordinating, complementary, associating, linking and integrating. Bybee's integration model was obtained for this study.

Teachers' Role in STEM Integration

Learning science through engineering is challenging. The biggest problem in integrating the engineering design process into the learning environment was the inability of the integration of science and mathematics effectively in the context. Teachers need to hold certain skills and knowledge so that they can integrate technology and engineering concepts into their classroom practices (Akaygun & Aslan-Tutak, 2016). Therefore, the role of the teacher is critical in this process. Since high-quality teachers are instrumental in positively affecting students' attitudes, motivation, and achievement, providing teachers with adequate support via effective professional development is vital to ensure our students are adequately prepared to enter our increasingly technologically-driven world as "STEM literate" citizens (McDonald, 2016). Yet, often integrated STEM instruction is not an intentional part of teacher education programs, and most pre-service and in-service teachers lack adequate integrated STEM exposure (O'Brien, Karsnitz, Sandt, Bottomley & Parry, 2014).

Although pre-service STEM teacher education should include STEM content, pedagogy, and conceptualization, the literature suggests no leading conception of STEM education, and little is known about teachers' thinking about STEM (Radloff & Guzey, 2016). One of the biggest educational challenges for K-12 STEM education is that few general guidelines or models exist for teachers to follow regarding how to teach using STEM integration approaches in their classroom (Wang, Moore, Roehrig & Park, 2011). Therefore, for effective integration it is helpful to know how pre-service teachers are conceptualizing and understanding STEM education.

Literature Review about Teachers' Beliefs, Conceptions and Perceptions

How teachers conceptualize, interpret, and subsequently enact STEM content and engineering impacts the learning experiences they provide in their classrooms (Diefes-Dux 2014). However, there are only a few research done in this area. For example, Wang et al. (2011) conducted a multi-case case study with three middle school teachers to gain a better understanding of teachers' beliefs about and perceptions of STEM integration, and to examine the connections between beliefs about and perceptions of STEM integration and teachers' classroom practices. They obtained the following results: First, the problem solving process was a key component to integrate STEM disciplines. Second, teachers in different STEM disciplines had different perceptions of STEM integration and that leaded to different classroom practices. Third, technology was the hardest discipline to integrate in these cases. And finally, teachers were aware of the need to add more content knowledge in their STEM integration. Siew, Amir and Chong (2015) investigated the perceptions of 25 pre-service and 21 in-service Malaysian science teachers in adopting an interdisciplinary project-based STEM approach to teaching science. Data on teachers' perceptions were captured through surveys, interviews, open-ended questions and classroom discussion before and at the end of the eight-hour workshop. They indicated that STEM professional development workshops could provide insights into the support required for teachers to adopt innovative, effective, project-based STEM approaches to teaching science in their schools.

In their study, Guzey, Moore and Harwell (2016) worked with 48 teachers by implementing conversion mixed method design. The teachers participated in a year-long professional development program on STEM integration, and they designed 20 new engineering design-based STEM curriculum units. Comparisons among the STEM units showed that mathematics integration and communicating mathematics, science, and engineering thinking were not found to strongly contribute to the overall quality of the STEM units (Guzey et al., 2016). Radloff and Guzey (2016) explored 159 pre-service STEM teacher conceptions of STEM education by using an open-ended survey. Their study yielded many findings and future directions. High variation existed in both textual and visual conceptions of STEM education, not readily connected with teacher experiences. Although there were commonalities in responses (for example Interconnected visualizations), new visualizations were found as well (Radloff & Guzey, 2016). Dare, Ellis and Roehrig (2018) designed a phenomenological multiple case study to understand nine science teachers' first-time experiences in implementing integrated STEM curricular units in their middle school physical science classrooms. Their results showed three distinct cases of STEM integration throughout curriculum implementations as low, medium, and high degrees. They revealed three themes that varied across teachers' experiences: the nature of integration, choosing between science and engineering, and student engagement and motivation. More research is needed to identify teachers' beliefs about and conceptions of STEM to provide professional development for teachers about STEM integration.

References

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing stem conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 56-71.

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3–11.

Bybee, R. (2013). *The case of STEM education: Challenges and opportunities*. Arlington, TX: NSTA Press.

Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education, 5* (4)

Diefes-Dux, H. A. (2014). In-service teacher professional development in engineering education: Early years. In S. Purzer, J. Strobel and M. E. Cardella (Eds.), *Engineering in precollege settings: Synthesizing Research, Policy, and Practices.* West Lafayette, IN: Purdue University Press.

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building Up STEM: An Analysis of Teacher-Developed Engineering Design-Based STEM Integration Curricular Materials. *Journal of Pre-College Engineering Education Research (J-PEER), 6*(1), Article 2.

Honey, M., Pearson, G., & Schweingruber, A. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. Washington, DC: National Academies Press.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11).

Krajcik, J., & Delen, I. (2017). How to support learners in developing usable and lasting knowledge of STEM. *International Journal of Education in Mathematics, Science and Technology, 5*(1), 21-28.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM Integration: Teacher Perceptions and Practice. *Journal of Pre-College Engineering Education Research (J-PEER), 1*(2), Article 2.

McDonald, C. V. (2016). STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. *Science Education International, 27* (4), 530-569

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In J. Strobel, S. Purzer and M. Cardella (Eds.), *Engineering in precollege settings: Research into practice*, (pp. 35–59). West Lafayette, IN: Purdue University Press.

Moore, T. J., Johnson, C. C., & Peters-Burton, E. E. (2015). The need for a STEM road map. In C. C. Johnson, E. E. Peters-Burton, and T. J. Moore (Eds.), *STEM road map: A framework for integrated STEM education* (pp. 3–12). New York, NY: Routledge.

National Academy of Engineering and National Research Council. (2014). STEM Integration in K–12 Education: Status, Prospects, and an Agenda for Research. Washington, DC: The National Academies Press.

O'Brien, S., Karsnitz, J., Sandt, S., Bottomley, L., & Parry, E. (2014). Engineering in preservice teacher education. In S. Purzer, J. Strobel and M. E. Cardella (Eds), *Engineering in pre-college settings: synthesizing research, policy, and practices* (pp. 277–300). West Lafayette, IN: Purdue University Press.

Radloff, J., & Guzey, S. (2016). Investigating Preservice STEM Teacher Conceptions of STEM Education. *Science Education Technology, 25*, 759–774.

Roehrig, G. H., Wang, H. H., Moore, T. J., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics, 112*(1), 31-44.

Siew, N. M., & Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *Springer Plus, 4*(8)

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM education: A project to identify the missing components*. Intermediate Unit 1. Center for STEM Education and Leonard Gelfand Center for Service Learning and Outreach, Carnegie Mellon University, Pennsylvania.

Wang, H. H., Moore, T. J., Roehrig, G. H., Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1–13.

Wang, H. H. (2012). *A New Era of Science Education: Science Teachers' Perceptions and Classroom Practices of Science, Technology, Engineering, and Mathematics (STEM) Integration*. Unpublished doctoral dissertation, The University of Minnesota, Minneapolis, MN.

Vasquez, J., Sneider, C., & Comer, M. (2013). *STEM lesson essentials, grades 3–8: Integrating science, technology, engineering, and mathematics*. Portsmouth, NH: Heinemann.

Integration of Transdisciplinary STEM Approach to Single Discipline-Based National Education Systems

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Introduction

The global competition environment requires continuous self-renewal of professions and citizens. For this, countries, sectors, universities, schools, academicians, teachers and students should acquire new knowledge, skills and competences. This requirement can be met by STEM training. STEM is an interactive combination of science, technology, engineering and mathematics. STEM is a transdisciplinary phenomenon. It is multidisciplinary but, much more than a simple sum of these disciplines. STEM is a holistic approach. As in many other countries there are single-disciplinary training system and curriculum in Turkey. In occupations, the situation is a little further. Mechatronics and software development are a good example of this, but not insufficient. The training provided at our K12 schools includes all the elements of STEM, but due to their inadequacy, we remain at the bottom of PISA, TALIS, TIMMS and similar international assessments. The situation is also valid for our universities and faculties. Our universities cannot enter to the upper rank of scientific success and their graduates cannot find a job for employment at national or international markets. On the other hand, with the grant support of the 4000 series programs of TUBITAK's Science and Society Department, hundreds' of STEM projects were being realized eve year at different schools. We are very interested in the efforts of Erasmus + projects on STEM. In these activities, we see that the interdisciplinary STEM projects were conducted by the students and teachers of disciplinary-based national curricula and education system. We feel the hidden walls between the STEM approach and science, physics, chemistry, biology lessons. Mathematic teaching is completely a problem as in all countries. In this digesting article, we will discuss how this interdisciplinary education required by the STEM approach will be adapted to our current discipline education system. For this, the documents were reviewed and the subjects was discussed with the teachers, parents and education faculties during the different STEM activities.

The curriculum is a framework for setting out the aims of a program of education, including the knowledge and understanding to be gained at each stage (intent); for translating that framework over time into a structure and narrative, within an institutional context (implementation) and for evaluating what knowledge and understanding pupils have gained against expectations (impact/achievement).

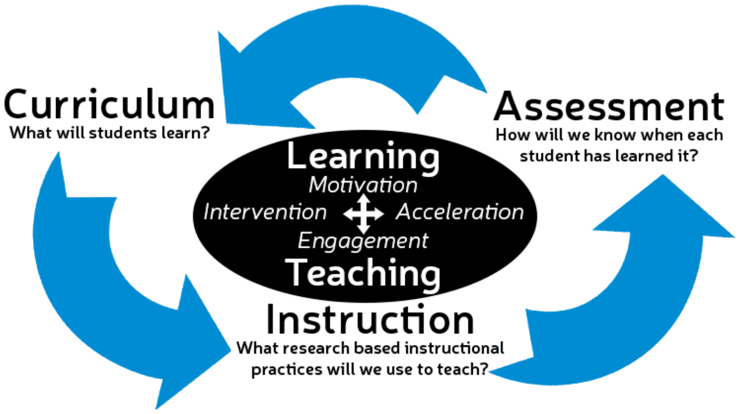

Figure 1. The Interaction of Curriculum, Assessment and Instruction

To understand the necessity pf the STEM approach, we will first summarize the international education and training policies, targets and strategies. The 21st century skills are a set of abilities that students need to develop in order to succeed in the information age, as given in the following diagram.

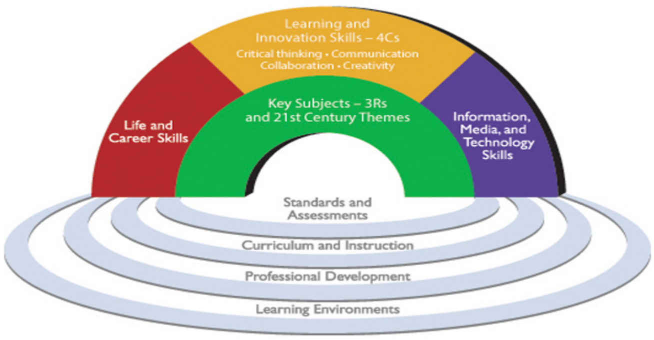

Figure 2. 21st Century Skills

Sustainable Development Goals

STEM education have an important role and impact in preparation of the pupils for 21st century skills such as complex problem solving, critical thinking, digital literacy and collaboration skills. United Nations defines the fourth goal of sustainable development as quality education.

Figure 3. Sustainable Development Goals by UN

Eight Basic Competencies

European Commission's Recommendation 2006/962/EC defines the key competences for lifelong learning as follow. Turkey targets this competencies in her national education strategy.

1. Communicating in a **mother tongue**: ability to express and interpret concepts, thoughts, feelings, facts and opinions both orally and in writing.

2. Communicating in a **foreign language**: as above, but includes mediation skills (i.e. summarizing, paraphrasing, interpreting or translating) and intercultural understanding.

3. **Mathematical, scientific and technological competence**: sound mastery of numeracy, an understanding of the natural world and an ability to apply knowledge and technology to perceived human needs (such as medicine, transport or communication).

4. **Digital competence**: confident and critical usage of information and communications technology for work, leisure and communication.

5. **Learning to learn**: ability to effectively manage one's own learning, either individually or in groups.

6. **Social and civic competences**: ability to participate effectively and constructively in one's social and working life and engage in active and democratic participation, especially in increasingly diverse societies.

7. **Sense of initiative and entrepreneurship**: ability to turn ideas into action through creativity, innovation and risk taking as well as ability to plan and manage projects.

8. **Cultural awareness and expression**: ability to appreciate the creative importance of ideas, experiences and emotions in a range of media such as music, literature and visual and performing arts.

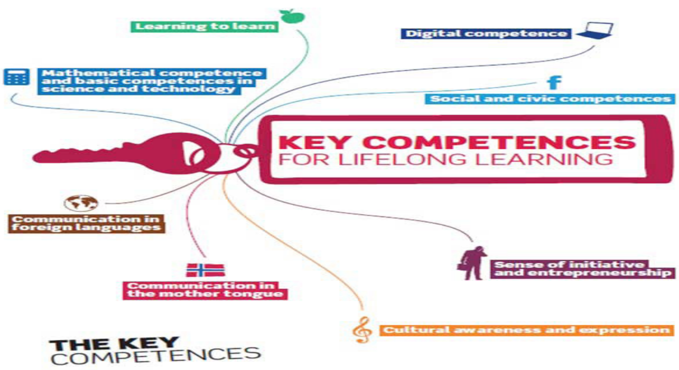

Figure 4. Key Competencies for Lifelong Learning

Figure 5. Students Competencies

The National Curriculum of MoNE Turkey

In Turkey, there is continuously rising interest in the STEM approach and applications. Public schools, as well as private schools, carry out many STEM practices, seminars, applications, festivals etc. The interest is mostly in secondary and high school level. Science fairs and science olympics by the financial and technical support of the Science and Society Department of TUBITAK highly increased this interest. In many schools coding training was provided and robot competitions were organized. STEM and Maker festivals are held. There is an increase in the number of thesis studies completed and scientific articles published on STEM. Our schools participate in STEM projects within the scope of Erasmus. In the national education curriculum and training strategy, STEM professions, STEM courses and practices was given importance. In addition to science courses technology, design and entrepreneurship courses are offered to students as compulsory or elective. However, we cannot say that the national curriculum and STEM practices and approaches strictly matching. The systematic studies are not sufficient. The national curriculum and the depending textbooks, programs, laboratories, teaching and learning techniques do not encounter the requirements and the needs of the future economy and competitiveness. The effects of single-disciplinary education have been observed in schools and teachers for many years. So, the change from single discipline to transdisciplinary system of education needs some time and huge effort. Each of the teachers of physics, chemistry, biology, mathematics and technology speaks positively about STEM. However, we do not see that teachers from different disciplines come together and do common activities. The laboratories of our schools are insufficient. The capacity of education faculties which are more than 80 all over the Tukey, is not sufficient for the STEM education. No program exists on STEM teacher training in university curriculums. In developed countries, STEM is considered to be a tool for more human resource preparation in engineering. However, the situation is somewhat different in Turkey. STEM subject is considered as a means of improving the quality of education in K12 schools in Turkey.

HASS and STEM

We may group the sciences as STEM disciplines, CAD (Creative Arts and Design) disciplines, Humanities, Social Sciences. We may call the non-STEM disciplines as HASS (Humanities, Arts and Social Sciences). STEM disciplines have been regarded as the primary source of innovation and competitiveness.

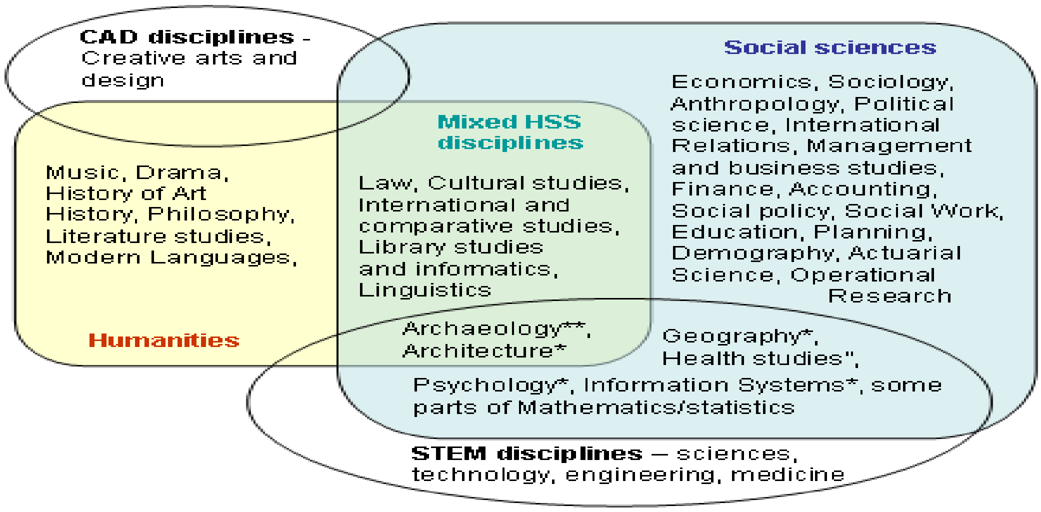

Figure 6. HASS and STEM Disciplines

Learning Objectives

To understand better the importance of STEM approach, we have to have brief look to the learning domains. The Learning Objectives were classified as cognitive, affective and psychomotor as shown in Figure 7.

- Cognitive domain (intellectual capability, i.e., knowledge, or ‘think’)
- Affective domain (feelings, emotions and behavior, i.e. attitude, or ‘feel’)
- Psychomotor domain (manual and physical skills, i.e. skills, or ‘do’)

Each of the domains were explained at the following table 1. So, you may think on the relations of STEM approach on each domain and steps. STEM and in general, education and training is closely related and interconnected with the world of work. So, we have to look a short look to the international coding system of education. ISCED is also interconnected with ISCO International Code of Occupation.

International Standard Code of Education

00 Generic programs and qualifications

01 Education

02 Arts and Humanities

03 Social Sciences, Journalism and Information

04 Business, Administration and Law

05 Natural Sciences, Mathematics and Statistics

06 Information and Communication Technologies

07 Engineering, Manufacturing and Construction

08 Agriculture, Forestry, Fisheries and Veterinary

09 Health and Welfare

10 Services

Table 1. Learning Domains and the Instructional Behavioral Term

Cognitive Domain of Learning (mental skills: KNOWLEDGE)	
Remembering	Identify, label, list, recall, recognize, match, name, select, tell
Understanding	Classify, compare, contrast, demonstrate, explain, extend, illustrate, infer, interpret, relate, outline, show, summarize, translate
Applying	Use, carry out, provide, respond, apply, build, choose, develop, model, organize, select, solve, utilize
Analyzing	Analyze, assume, categorize, classify, compare, conclude, contrast, discover, dissect, distinguish, examine, inspect
Evaluating	Appraise, assess, award, choose, criticize, defend, disprove, estimate, interpret, judge, rate, support, justify
Creating	Create, design, assemble, generate, build, change, choose, combine, formulate, elaborate, modify, compose, invent, improve, predict, plan
Psychomotor Domain of Learning (manual or physical SKILLS)	
Perception	Distinguish, hear, see, smell, taste, touch
Set	Adjust, approach, locate, place, position, prepare
Guided Response	Copy, determine, discover, duplicate, imitate, inject, repeat
Mechanism	Adjust, build, illustrate, indicate, manipulate, mix, set up
Adaptation	Adapt, built, change, develop, supply
Organization	Construct, create, design, produce
Affective Domain of Learning (growth in feelings and emotional areas: ATTITUDE)	
Receiving	Asks, chooses, describes, follows, gibes, holds, locates, points to, relies, uses
Responding	Answers, assists, complies, conforms, greets, performs, practices, presents, recites, reports
Valuing	Completes, explains, initiates, invites, joins, justifies, proposes, shares, studies
Organization	Adheres, alters, arranges, defends, generalizes, integrates, orders, prepares, relates
Characterization	Acts, discriminates, displays, influences, modifies, proposes, qualifies, questions, revises, serves, solves, verifies

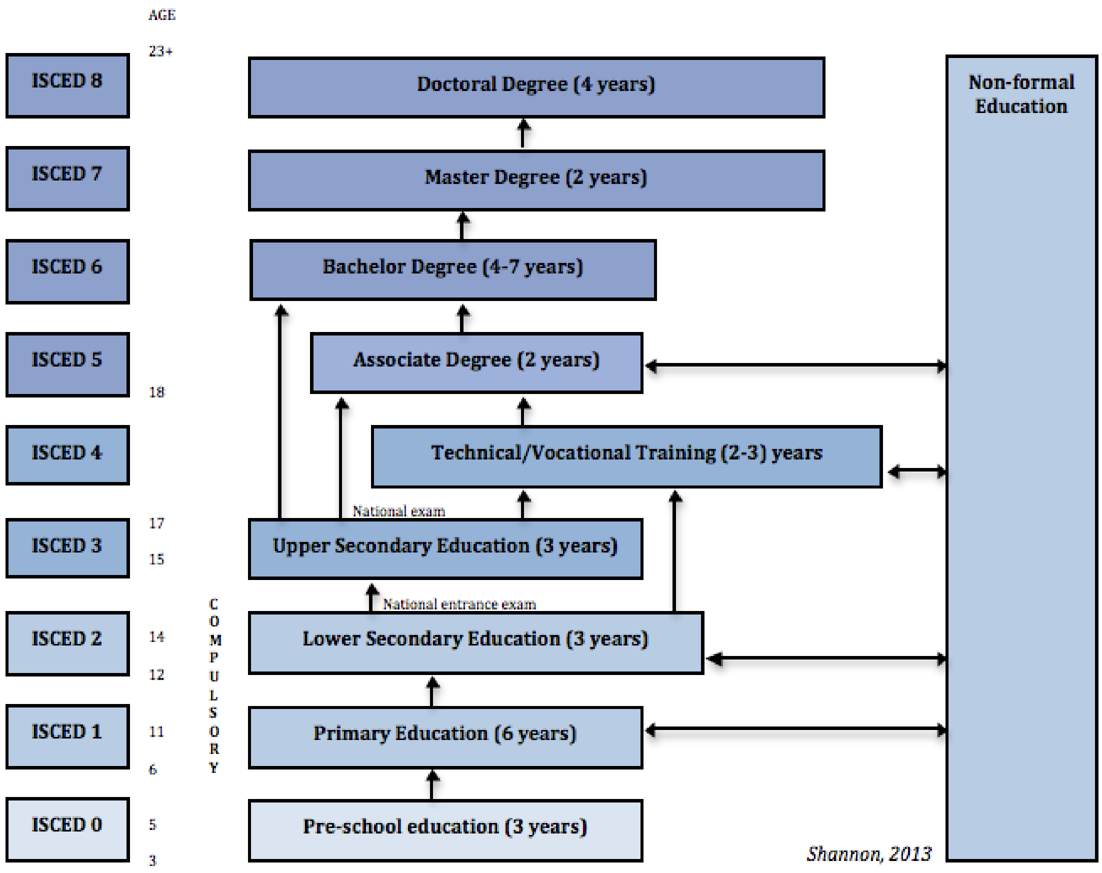

Figure 7. ISCED Codes of Level of Education

Types of Disciplines

Disciplinarities may be defined as follow over a theme;

- Intradisciplinary: working within a single discipline.
- Crossdisciplinary: viewing one discipline from the perspective of another.
- Multidisciplinary: people from different disciplines working together, each drawing on their disciplinary knowledge.
- Interdisciplinary: integrating knowledge and methods from different disciplines, using a real synthesis of approaches.
- Transdisciplinary: creating a unity of intellectual frameworks beyond the disciplinary perspectives.

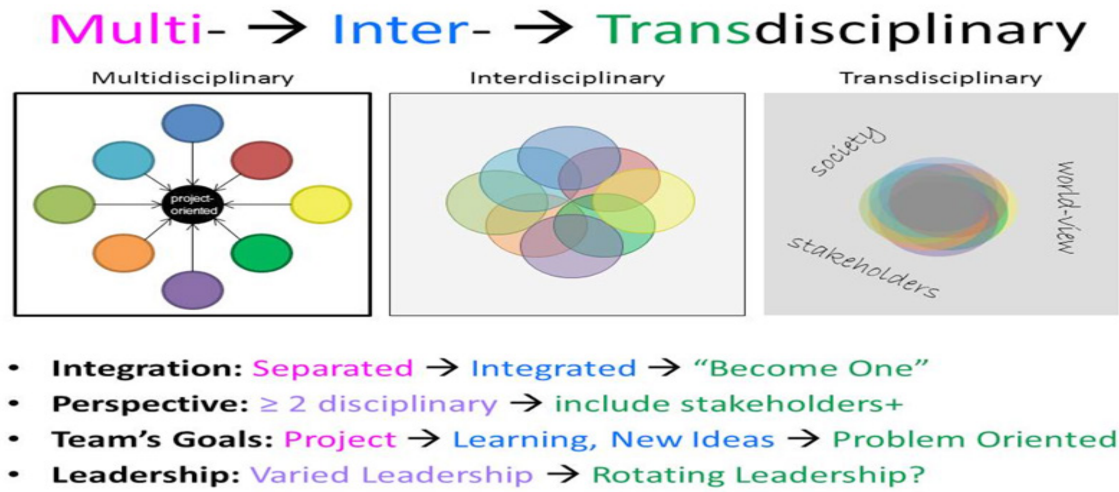

Figure 8: The Order of Disciplines

Definition of STEM and its primary objectives

STEM includes physical and natural sciences, technology, engineering and mathematics disciplines, topics, or issues including environmental science education or environmental stewardship. The STEM education have one of the followings as a primary objective;

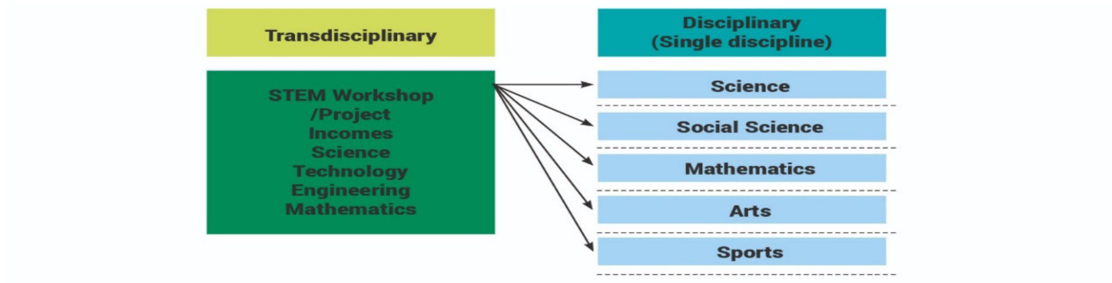

Figure 10. Transdisciplinary Education and STEM Approach

- Learning to develop STEM skills, practices, or knowledge of students or the public.
- Engagement to increase learners' interest in STEM, their perception of its value to their lives, or their ability to participate in STEM.
- Pre- and In-Service Educator or Education Leader Performance to train or retain STEM educators (K– 12 pre-service or in-service, postsecondary, and informal) and education leaders to improve their content knowledge and pedagogical skills.
- Postsecondary STEM Degrees to increase the number of students who enroll in STEM majors, complete STEM credentials or degree programs, or are prepared to enter STEM careers or advanced education.
- STEM Careers to prepare people to enter into the STEM workforce with training or certification (where STEM-discipline-specific knowledge and skill are the primary

focus of the education investment).

- STEM System Reform to improve STEM education through a focus on education system reform.
- Institutional Capacity to support advancement and development of STEM personnel, programs, and infrastructure in educational institutions such as universities, informal education institutions, and state and local education agencies.
- Education Research and Development for the evidence-based STEM education models and practices

STEM approach is not only transdisciplinary but also a holistic approach. It is explained at Figure 11 as the combination of the scientific disciplines, learning theories, learning paradigms and key concepts.

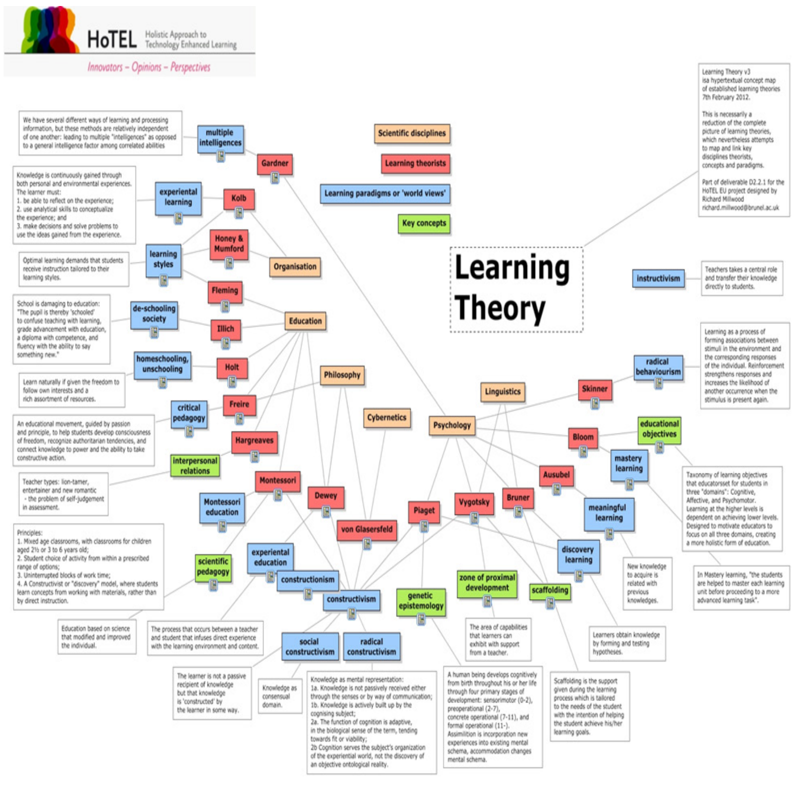

Figure 11. The Holistic Approach and Learning Theories

STEM Skills

Morrison defined the STEM integration classroom students as problem solvers, innovators, inventors, logical thinkers, capable to understand and develop the skills needed for self-reliance and technological literacy. STEM skills include numeracy and the ability to generate, understand and analyze empirical data including critical analysis, an understanding of scientific and mathematical principles, the ability to apply a systematic and critical assessment of complex problems with an emphasis on solving them and applying the theoretical knowledge of the subject to practical problems, the ability to communicate scientific issues to stakeholders and others, ingenuity, logical reasoning and practical intelligence.

STEM Integration

It was defined by Moore as the merging of the four pillar disciplines of science, technology, engineering, and mathematics in order to,

- deepen student understanding of each discipline by contextualizing concepts,
- broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts,
- increase interest in STEM disciplines by increasing the pathways for students to enter the STEM fields.

STEM integration is an interdisciplinary teaching approach, which removes the barriers between the four disciplines and goes beyond simply blending traditional types of understandings. Jan Morrison at all accepts STEM as a unitary idea, not simply a grouping of the four disciplines in a convenient, pronounceable acronym.

Blended Learning

STEM is somehow different from the traditional science and mathematics education. STEM is the blended learning environment and showing students how the scientific method can be applied to everyday life. It teaches students computational thinking and focuses on the real world applications of problem solving. As mentioned before, STEM education begins while students are very young and must continue at undergraduate, graduate and lifelong learning levels.

- **Elementary school**: STEM education focuses on the introductory level STEM courses, as well as awareness of the STEM fields and occupations. This initial step provides standards-based structured inquiry-based and real world problem-based learning, connecting all four of the STEM subjects. The goal is to pique students' interest into them wanting to pursue the courses, not because they have to. There is also an emphasis placed on bridging in-school and out-of-school STEM learning opportunities.
- **Middle school**: At this stage, the courses become more rigorous and challenging. Student awareness of STEM fields and occupations is still pursued, as well as the academic requirements of such fields. Student exploration of STEM related careers begins at this level, particularly for underrepresented populations.

- **High school**: The program of study focuses on the application of the subjects in a challenging and rigorous manner. Courses and pathways are now available in STEM fields and occupations, as well as preparation for post-secondary education and employment. More emphasis is placed on bridging in-school and out-of-school STEM opportunities.

Some Countries' STEM Strategies

The educational systems of all countries naturally are the ones which may be remedied as it continue. Due to nature of education, there is no chance for countries to stop the education system, wait for designing a new one and to start again with a new program or curricula. So educational strategies must be determined so that its actions will adapt the existing cases and members to the ones as the education and training goes on.

The STEM Strategy of USA started 30 years before to keep itself as the most competitive in the global economy. The National Science Board (NSB) report titled as the Undergraduate Science, Mathematics and Engineering Education in 1986 was the first U.S. policy guidance document on STEM education. Strategies for Revitalizing Undergraduate Education in 1996, American Competitiveness Initiative in 2006 and Change the Equation in 2010 and STEM 2026 was the update of policy documents. As an action, the followings qualitative and quantitative targets was planned to realize;

- Improve STEM Instruction: Prepare 100,000 excellent new K-12 STEM teachers by 2020, and support the existing STEM teacher workforce;

- Increase and Sustain Youth and Public Engagement in STEM: Support a 50 percent increase in the number of U.S. youth who have an authentic STEM experience each year prior to completing high school;

- Enhance STEM Experience of Undergraduate Students: Graduate one million additional students with degrees in STEM fields over the next 10 years;

- Better Serve Groups Historically Under-represented in STEM Fields: Increase the number of students from groups that have been underrepresented in STEM fields that graduate with STEM degrees in the next 10 years and improve women's participation in areas of STEM where they are significantly underrepresented;

- Design Graduate Education for Tomorrow's STEM Workforce: Provide graduate-trained STEM professionals with basic and applied research expertise, options to acquire specialized skills in areas of national importance, mission-critical workforce needs for the CoSTEM agencies, and ancillary skills needed for success in a broad range of careers.

Some of the STEM Programs at USA

Many programs were started at USA to integrate STEM to schools. Some of them are the followings;

- The Programs with Primary STEM Emphasis
- Math Science Partnerships
- Teacher Incentive Fund - STEM
- RESPECT and the STEM Master Teacher Corps
- Minority Science and Engineering Improvement Program
- Hispanic Serving Institutions STEM and Articulation Programs
- Fund for the Improvement of Education – K-16 Math Initiative
- Upward Bound Math and Science Program
- National Science and Mathematics Access to Retain Talent Grant Programs
- Research Programs with Primary STEM Emphasis
- Mathematics and Science Education
- Education Research Grants—Effective Teachers and Effective Teaching Topics
- Education Technology
- Special Education Research Grants—Professional Development for Teachers
- Mathematics and Science Education: Special Education Research
- Technology for Special Education
- Programs with STEM Grantee Selection Priority:
- Race to the Top
- Investing in Innovation
- 21st Century Community Learning Centers
- National Professional Development Program
- Supporting Effective Educator Development

- Transition to Teaching
- Teacher Quality Partnership
- Magnet Schools Assistance
- Advanced Placement Incentive Program
- Fund for the Improvement of Postsecondary Education
- Predominately Black Institutions
- Teachers for a Competitive Tomorrow
- Graduate Assistance in Areas of National Need
- Ronald. E. McNair Post-baccalaureate Achievement Program
- Master's Degree Programs at Historically Black Colleges and Universities
- General Programs that Support STEM Education:
- ESEA Flexibility
- Career and Technical Education: Basic Grants to States
- Trade Adjustment Assistance Community College and Career Training Grants
- Small Business Innovation Research
- U.S. Department of Education Green Ribbon Schools

EU Strategy for STEM

European Commission highly supports the integration of STEM to pre-school, K12 and university mainly by the ERASMUS+ program. Really, the EU needs STEM skilled human sources to reach the EU2030 goals and to rise its competitiveness. STEM Alliance and SCIENTIX are the most important tools of the European Commission on STEM.

China STEM Strategy

China Office of the State Council issued The Chinese STEM Action Plan in 2016. The plan support the horizontal cooperation among disciplines and conducting interdisciplinary practice and inquiry activities in secondary school. Educational Informatization Planning in 13th Five-Year issued by China Ministry of Education explores the application of information technology in new education modes such as Maker Space, Interdisciplinary

Learning and Maker Education, enhancing students' information literacy, innovative awareness, innovative ability and digital learning habits. Full-time compulsory education primary school science curriculum standards in 2017 stated that science education should start from real situations that help students take the initiative to learn. Science education should encourage students to study actively. Students should be endowed with personality to continuously improve their inquiry skills. The standards also point out that science is closely related to other subjects and advocate interdisciplinary learning, namely STEM education. In this condition, Primary and secondary general practice curriculum guidelines suggests four types of activities: investigation and inquiry, community service, design and production, professional experience. In 2001, Student Research Program was launched in all over the country, listed the high school compulsory curricula. Different models have been developed in the Chinese curriculum. As it can be seen in the table given below, the main discipline of biology is chemistry. The other disciplines i.e. technology, mechanics, informatics can support the discipline of biology. In the second model, a discipline can be combined with disciplines such as AI or MM. The third model is the merge of more than three disciplines.

Table 2. STEM Models in Chinese Curriculum

Model	Couple A+B	Star A + X	NESTED Multidiscipline 'A+B+C'
Field	Biochemistry Biotechnology Biomechanics Bioinformatics Social psychology Geography VR Design	Artificial Intelligence Mathematical Modeling	Computing and visualization Robotics Technology and Design Virtual Reality Digital Image Processing and Pattern Recognition Traditional Handicraft UAV Science and engineering UAV Technology Innovation Practice Mechatronics Space Science Aerospace Computer Vision and Deep Learning Electronic and Information Engineering Information and Communication Engineering

German STEM Strategy

The STEM education in Germany was as called MINT (Mathematik, Informatik, Naturwissenschaft und Technik) which was connected with vocational education.

MINT offer special curriculum, program and scholarship for the talented youth through extracurricular school lab collaboration.

Australian STEM Strategy

The Australian federal government decided on a new policy National Innovation and Science Process in 2015 and the board of education accepted National Science, Technology, Engineering and Mathematics School Education Strategy 2016—2026. The universities and industries to create online demonstration modules for STEM teaching practices. They also establish STEM career learning exchange platforms.

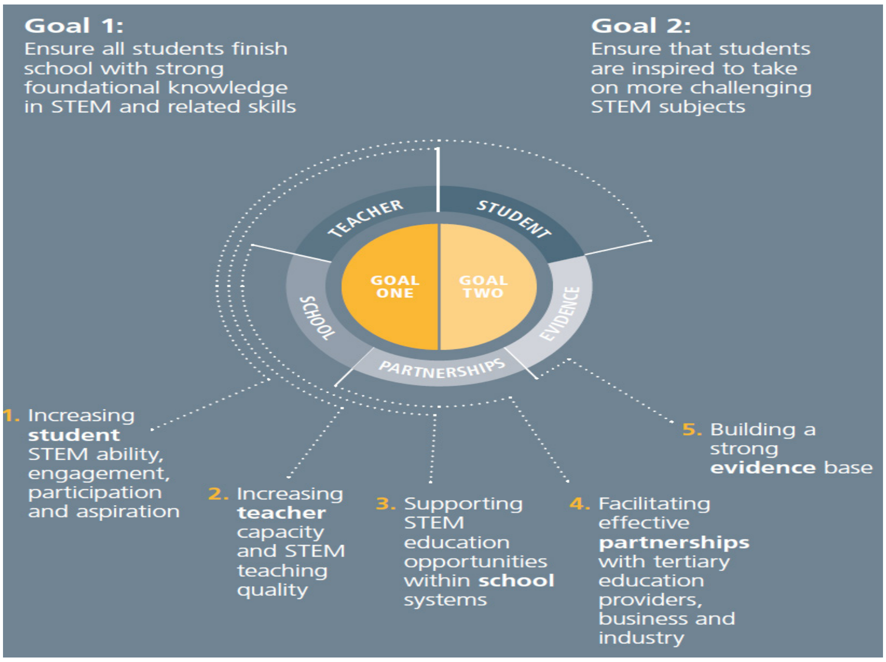

Figure 12. The Goals of STEM Strategy of Australian Education System

STEM in Russia

When the communist regime in Russia came to an end in 1991, the education system was very strong in technology and engineering. Mathematics was compulsory in all areas. With the transition to the free market economy, the new job opportunities were arising outside the STEM. High wages were given to these areas as there were not enough human resources. Thus, young people started to focus mainly on service sectors such as banking, marketing etc. more than STEM areas. This led to a weakening of the STEM area in Russia. However, Russia is at high rank in international classifications like PISA. There is not enough literature about the Russia's STEM activities.

Turkey STEM Strategy

The rapid change in science and technology, the changing needs of the individual and the society, the innovations and developments in the teaching theory and approaches of learning have directly affected the roles expected from the individuals. This change defines the individual who produces knowledge, can use functionally in life, can solve problems, think critically, have entrepreneurial, stable, communicate skills, empathy, contribute to society and culture. The educational programs that will serve to educate individuals with this qualitative texture are prepared in a simple and understandable manner, which takes individual differences into consideration rather than a structure that conveys information. For this purpose, it is aimed to repeat the achievements and explanations with a helical approach at different subject and class levels on the one hand, and the learning outcomes that are aimed to be acquired holistically and at once. The acquisitions and explanations in both groups are competent, up-to-date, valid and relevant to life. These achievements and explanations, which define their boundaries, point to a simple content from a perspective that provides integrity in the perspective of values, skills and competences at the level of classes and levels of education. Thus, a total of integrated curricula has been established around the values, skills and competencies associated with other disciplines and daily life, which lead to the use of metacognitive skills, provide meaningful and permanent learning, are associated with solid and prior learning. For realizing this targets, the teachers and school principal have a critical role. The function of teacher with single discipline system of curricular was changed importantly in the transdisciplinary system

STEM integration classroom students are not only classical one but also should be able to perform as problem solvers, innovators, inventors, logical thinkers, able to understand and develop the skills needed for self-reliance and technological literacy. The student also explores the engineering as a discipline and the engineering design cycle, mathematical connections to engineering design cycles lessons, exploring mathematical thinking through model-eliciting activities, integrating technology to enhance learning of science, engineering, and mathematics, orchestrating student discussions around STEM concepts. The education and training of the student is no more limited with the school and classroom. Out of school learning have more share now than ever before.

Conclusion and Recommendations

The List of STEM Curriculum Articles indexed in ERIC Database gives 1.528 articles. The number of Erasmus+ projects on STEM is more than . TUBİTAK supports STEM projects of more than 6.000 schools per year. Robotics, coding, maker etc. training is expanding at university and K12 school levels. But, STEM activities are not sufficient and sustainable yet in Turkey. Content integration and context integration of STEM activities with national curriculum is not sufficient.

We may offer the following precautions for the integration of national curriculum to STEM for supporting the competitiveness of Turkey.

- Change of mind and understanding the STEM at all levels of the national education system,
- Integration of national curriculum and programs to the STEM approach.
- Integration of assessment and other regulations to STEM applications
- Integration of in-service teacher training programs to STEM requirements
- Integrate the curriculum of education faculties in training of teachers
- Integration of school principals and teachers for conducting STEM projects.
- Develop STEM Leaders at school.
- Integration of textbooks to STEM
- Donation of the laboratories with STEM equipment
- Integration of parents and students who are highly interested in STEM disciplines
- Content integration and context integration of STEM activities with national curriculum must be realized as soon as possible.

References

Between historical advantages and global STEM disciplines matter in Russia, Anna Smolentseva. 2013. http://dro.deakin.edu.au/eserv/DU:30059041/tytler-stemcountry-2013.pdf

China National Science Quality Action Plan (2016-2020) , http://www.stats.gov.cn/wzgl/ywsd/201603/t20160315_1331000.html

China Education 13th Five Year Plan, http://www.moe.gov.cn/srcsite/A16/s3342/201606/t20160622_269367.html

China Education Curriculum, 2017, http://www.moe.edu.cn/srcsite/A26/s8001/201702/W020170215542129302110.pdf

Changing the Equation of Education, Whitehouse, USA 2016. https://obamawhitehouse.archives.gov/blog/2010/09/16/changing-equation-stem-education

European Schoolnet, http://www.eun.org/focus-areas/stem

Fogarty, Robin. "Ten ways to integrate curriculum." Educational leadership 49.2 (1991): 61-65. http://www.ascd.org/ASCD/pdf/journals/ed_lead/el_199110_fogarty.pdf

Inspiring All Australians in Digital Literacy and STEM, 2016. https://www.education.gov.au/news/inspiring-all-australians-digital-literacy-and-stem-0

Kärkkäinen, K. & S. Vincent-Lancrin (2013). "Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative", OECD Education Working Papers, No. 91, OECD Publishing, Paris. http://dx.doi.org/10.1787/5k480sj9k442-en

Maximizing the Social, Policy And Economic Impacts Of Research In The Humanities And Social Sciences Report to the British Academy from the LSE Public Policy Group, July 2008. http://www.lse.ac.uk/government/Assets/Documents/pdf/research-groups/ppg/legacy-pdf/BA-Final-Report-July-2008.pdf

Moore, T.J. (2008). STEM integration: Crossing disciplinary borders to promote learning and engagement. Invited presentation to the faculty and graduate students of the UTeachEngineering, UTeachNatural Sciences, and STEM Education program area at University of Texas at Austin, December 15, 2008.

Moore, T.J. (2010). Implementing K-12 Engineering Standards through STEM Integration. National Science Foundation Faculty Early Career Development (CAREER) Program, Engineering Education Division.

Morrison Jan, Raymond V., Buzz Bartlett (2009) STEM as a Curriculum, an Experiential Approach. https://tr.scribd.com/doc/177596013/stem-as-curriculum

National Science Foundation. A History in Highlights 1950-2000, K-12 and Undergraduate Education, 2016. https://www.nsf.gov/nsb/documents/2000/nsb00215/nsb50/1980/k12. html

National Science Foundation. American Competitiveness Initiative 2016. http://www.nsf.gov/attachments/108276/public/ACI.pdf

National Science Foundation. Shaping the Future: Strategies for Revitalizing Undergraduate Education. Proceedings from the National Working Conference, 2016.

National Stem School Education Strategy, A Comprehensive Plan For Science, Technology, Engineering And Mathematics Education In Australia December 2015. http://www.educationcouncil.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf

STEM 2026 A Vision for Innovation in STEM Education, https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

STEM Integration, 2011.Teacher Perceptions and Practice. Journal of Pre-College Engineering Education Research 1:2, 1–13 DOI: 10.5703/1288284314636 Hui-Hui Wang, Tamara J. Moore, Gillian H. Roehrig, and Mi Sun Park University of Minnesota

STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research: Margaret Honey, Greg Pearson, and Heidi Schweingruber, Committee on Integrated STEM Education; National Academy of Engineering; National Research Council https://pdfs.semanticscholar.org/bac5/69ca108d7ac7c965748264190743161500 60.pdf

Tabar, V. (2018). Content Analysis of STEM Education Research in Turkey. Master Thesis, Van

The Curriculum Sean Harford, Director, Education, Ofsted NASUWT BME Consultation Conference 27 January 2018 ICC, Birmingham. https://www.slideshare.net/Ofstednews/the-curriculum-87255767

The Curriculum of MEB Schools, http://mufredat.meb.gov.tr/Programlar.aspx

The List of STEM Curriculum Articles Indexed in ERIC Database, https://eric.ed.gov/?q=STEM+Curriculum

The National Science and Technology Council (NSTC) Committee on STEM Education (CoSTEM), https://www.whitehouse.gov/ostp/nstc/

The White House, Preparing Americans with 21st Century Skills Science Technology, Engineering and Mathematics (STEM) Education in the 2015 Budget (2016) https://www.whitehouse.gov/sites/default/files/microsites/ostp/fy_2015_stem_ed.pdf

UNESCO Institute for Statistics 2011, ISCED: International Standard Classification of Education, viewed November 2018, http://www.uis.unesco.org/Education/Pages/international-standard-classification-of-education.aspx

Lessons from a First Year Lab: Constructing a Successful Virtual Environment in an Institute of Higher Education

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Introduction

According to the U.S. Department of Education (2015) public school teachers today are more disillusioned about their jobs than they have been in many years. One 2013 poll found that teacher satisfaction had declined 23 percentage points since 2008, from 62 percent to 39 percent very satisfied, the lowest level in 25 years. Unfortunately, a critical teacher shortage exists in Alabama. Specifically, a critical teacher shortage exists in the fields of science, technology, engineering, arts, mathematics (STEAM), and special education. Videotaping is one of many tools used in teacher preparation prorams for the purpose of improving teaching skills through reflection and discussion.

Quality teacher preparation programs that provide rich modeling and a plethora of hands on classroom opportunities for teachers in training are invaluable at the college level. The Council for the Accreditation of Educator Preparation (CAEP) encourages the use of technology, like videotaping, to facilitate ongoing learning for teacher candidates.

In teacher preparation, more effective practices are needed for preparing teacher candidates (U.S. Department of Education 2009b). The challenge also lies in finding an effective mechanism that provides essential learning experience and opportunities to refine teaching techniques to fidelity in a safely controlled and coordinated environment (Garland, Vasquez, & Pearl, 2012). One way to support teacher candidates is through the use of a virtual environment (VEs). The goal is to provide teacher candidates the opportunity to learn new skills and craft their practice through the VEs. Currently, Auburn University at Montgomery is the only university in the state of Alabama that offers the Virtual Avatar Laboratory (VAL) for teacher candidates. Research has shown an improvement in teaching methods with only four sessions in a VE (Abernathy, 2014). What if teacher candidates could be provided with at least four years of practice through the VAL? Imagine the VAL utilizing "rounds," borrowing from the medical model, which would allow teacher candidates to learn in the field from a number of mentor teachers in a variety of settings.

There is a need to provide authentic, controlled, and specific teaching experiences to teacher candidates. Faculty members have little control over what teacher candidates experience in the area schools that partner with colleges and universitites. It is difficult to guarantee that they are seeing evidenced based practices across content areas, behavior management, lesson planning, and assessment with a novice teacher. The goal, when placing teacher candidates, is to diminish the gap of their theories and implementation of said theories in preservice (Allsopp, DeMarie, Alverez-McHatton, & Doone 2006). It is imperative for future educators to have strong preparation experiences both in the field and in the college classroom. Pairing a teacher candidate with a single mentor for a semester of observation and student teaching, which is common in traditional preparation programs, may not be the optimal way to allow candidates to see expert teachers in action. Moore (2003) found in her study that mentors expected their teacher candidates to know and be able to implement specific strategies. So, if there are certain expectations from mentors, it would be important that teacher candidates practice and perfect a variety of strategies throughout their education program. It could take years of practice for someone to perfect rules, theories, or strategies (Erricson & And 1993). However, with the implementation of the VAL, the teacher candidates are being provided with an innovative tool that will enable them to explore, implement, and reflect on strategies for teaching and classroom management in an authentic environment.

The VAL provides teacher candidates the opportunity to learn new skills and craft their practice without placing "real" student/parent relationships at risk during the learning process. That is, if a teacher candidate performs poorly or wants to experiment with a new approach with the VAL, there is no adverse effect on any real student, but the experience feels real. A teacher candidate can also reflect on the lesson, determine what needs to be improved, and then try a new approach in the same environment without affecting "real" students (Dieker, 2017). One of the most important aspects of the system is that a faculty member can script an experience and then deliver it with fidelity and validity while being customized to the responses of teachers or students. The VAL evokes personalized learning and an authentic experience (i.e., suspension of belief) by providing a simulated, mixed-reality setting.

In the VAL, teacher candidates or administrators walk into a room where everything looks like a standard classroom including props, whiteboards, and students. Unlike the brick and mortar setting, the lab is a virtual setting and the students in the classroom are avatars. Depending upon the objectives of the session, the virtual students may behave in a way that offers student teachers an opportunity to practice their classroom management, pedagogical skills or both. Teacher candidates can interact with student avatars and review previous work, present new content to students, provide scaffolding or guided practice in a variety of content areas, and monitor students while they work independently or in small groups. In a VE, teacher candidates can learn instruction and management skills needed to become effective teachers and in-service teachers can sharpen and refine their existing skills. Furthermore, computer simulation provides unique benefits in that performance data can be recorded, compared with past performance, and tagged for analysis using a video tagging tool in conjunction with developed rubrics.

In conclusion, it is important that teacher candidates feel and are prepared when they start their first job. The best way to do that is through authentic practice and that is what the VAL can offer teacher candidates. This program will allow teacher candidates the opportunity to practice and perfect their own strategies without directly effecting students. Ultimately, getting more of these programs in colleges and universities will help with teacher preparedness. In order to create this laboratory, there are many steps and processes that one must go through. The goal is to address these steps and process and answer some of those questions in order to help create a successful first year laboratory. The questions that will be addressed are: (a) how do I fund the program? (b) who do I need support from? (c) what companies do I need to establish a relationship with? (d) what needs to be included in the budget? (e) how do I design the laboratory? (f) what ways can I market the new laboratory? (g) what steps do I need to take once the laboratory has been funded? (h) how do I have a successful first year laboratory?

Tips from the Director

Writing your grant

What are the weak areas of your program, college, or university? Writing a grant can be daunting. However, stay focused on the who, what, how, and where. The focus for this particular grant was to enhance teaching experiences for special education teacher candidates. The VAL grant funding was solely for College of Education (COE) use. All COE faculty can use the VAL for free, but others (in and out of the university) must pay an hourly rate. I found that focusing on COE needs with an emphasis on outside pay will hopefully help with future funding.

Developing your niche

What makes you unique? For the COE, our niche is that we are the only VAL in the state of Alabama. That makes us exclusive. Some labs focus on English Language Learners (ELL) as their niche. Working with STEAM and local school faculty or students on the Autism Spectrum Disorder (ASD) are other areas of need. Find something that would make your lab stand out. Even think of larger community needs if you can link it back to your university goals.

Working with the Institutional Review Board (IRB)

What research do you want to produce? Our focus was on "enhancing" teacher field placements, not replacing them. Enhancing the learning experience through parent-teacher conferences, principal-parent conferences, student behavioral issues, mock interviews, or counseling sessions just to name a few. Your IRB should all relate to your grant and desired niche. Don't reinvent the wheel!

Establishing friendships with Mursion, Inc.

Why should I use *Mursion, Inc.*? *Mursion, Inc*. is the virtual training company in which educators practice and master their skills through the original TLE TeachLivE Lab. They provide the training platform that is authentic, targeted, personalized, and interactive. The TLE TeachLivE Lab provides teacher candidates the opportunity to learn without placing "real" students or peers at risk during the learning process. That is, if a TLE TeachLivE Lab user performs poorly or wants to experiment with a new approach while using the TLE TeachLivE Lab, there is no adverse effect on any real student, but the experience feels real. One of the most important aspects of the system is that a faculty member can script an experience and then deliver it with fidelity and validity while being customized to the responses of teachers or students. A TLE TeachLivE Lab evokes personalized learning and an authentic experience (i.e., suspension of disbelief) by providing a physical environment in which everything looks like a classroom, yet users are in a computer simulated, mixed-reality setting. Furthermore, simulations provide unique benefits in that performance data can be recorded, compared with past performance, and tagged for analysis using a video tagging tool in conjunction with developed rubrics. Currently, *Mursion* is the only company in the United States that offers artificial intelligence enhanced by live human interactors. *Mursion* is a great, young company that can help you develop the needs of your lab. They can also build specific avatars to fit your lab needs. Their technology support staff is exceptional... something that is needed with this particular type of lab.

Seeking support from those within your institution

Who should I seek support from? Anyone! Most importantly, have the support of your dean first. For every "presentation" I made about starting a lab, I showed a TLE TeachLivE video. The technology, what it can do, how it works, and its implications are difficult to explain. Especially, to non-technology people. Every impromptu presentation I started with the "why" of the lab, how it can enhance learning, followed by a video. The video example usually drives it home. Follow up the video with all the different scenarios one can design. I have found that letting the person brainstorm out loud its use for their particular field works best. No need to add bells or whistles...the technology and the experience sells itself.

Generating the link to CAEP accreditation

Why should I care about accreditation? Any accrediting body is always looking for how universities improve or augment the learning experience. If your COE has difficulty finding ELL or secondary placements, you can build those needs in a lab. One could use it to focus on improving a weakness in a program area (STEAM, problem solving, to name a few!). Do some research and use the lab to your advantage.

Emphasizing university needs/goals

Why should I emphasize university needs and goals? To increase your likelihood of funding! If you are going for an in-house grant, tie in as many university needs/goals as you can. If the university can see the benefit beyond the institution, the better off you are at getting funded. For our particular grant, we align with all eight of the university wide goals.

Working with your administrator and budget

Why include an administrator? Your lab will become a small business and any help from an administrator is important in keeping equipment and payment in line. They are also helpful in keeping up with simulation specialist pay and opening up the lab if need be. They are an invaluable part of running a successful lab. To note, it is always good to have a second pair of eyes on a budget!

Designing the physical space of your laboratory

For the VAL, the dean gifted one office for the simulation specialist and one classroom for the grant. The VAL (gifted classroom) has a smartboard and computer in the front of the classroom for lectures. On the back wall is a mounted television with a computer behind it. This is the VAL. In front of the mounted television, is a checkered floor to keep students inside the lab while running simulations. The four windows in the VAL have frosted tint over the glass to minimize the sun and keep out the distraction of students walking by. The VAL was placed in the back of the room on purpose, this was to keep distractions to a minimum if someone were to come in during a simulation. This set up allows for a faculty member to lecture, provide examples, and then turn and start simulations if necessary. It is a great dual-purpose room, especially for those who want to rent out the space for an all-day event or professional development. See pictures below.

Meeting with upper administration for support and circulation

Why meet with upper administration? Your administrators are always out in the community. Have them “sell” your lab while out. No matter where they go, a lab is a source of pride, and can easily be worked into any conversation with local businesses. Let them do some advertising for you! Always invite them over when you have distinguished guests visiting.

Marketing your laboratory (name, logo, flyers, giveaways)

Why should I market my lab? Giving your lab a kitschy or memorable name gets it notoriety in and around your area. Think about your lab, your COE needs, community needs, and how you can enhance learning through your lab name. Enlist the help of your university marketing department, give them a presentation on the lab, and see what they design. Technology gurus love being in the VAL. Show the different ideas and mock ups to a group and get a feel for what looks good. I have full page flyers, half page flyers and quarter page flyers for all occasions. We also have cups, keychains, and pens to hand out to visitors. Keep them handy. Our elongated logo design is below.

VAL
VIRTUAL AVATAR LABORATORY
AUBURN UNIVERSITY AT MONTGOMERY • COLLEGE OF EDUCATION

Conceptualizing your webpage

What information do you want the general public to know? Our VAL webpage is dedicated to information about *Mursion*, the VAL, and current press releases. There is also a “More information” link. This is a survey that can be filled out for those who want to come visit or have questions about the VAL. This link is to Qualtrics, a survey design website. Every time someone completes a form, the director receives an email alert and can contact them promptly.

Hiring your simulation specialists

Hiring a simulation specialist is an import key to a successful lab. They “bring to life” the scenarios that you want to design for your participants. *Mursion* does an excellent job of advertising, recruiting, and training your simulation specialist. It is worth the extra money to have them during the hiring process. They will send over resumes, video interviews, and their grades earned during improvisation exercises for faculty to review. My area of expertise is in special education, not theatre, puppetry and improvisation. I am happy to leave that process to *Mursion* and decide upon those they send forward to the hiring committee.

Holding an open house

Why should we have an Open House? An Open House is a great opportunity to highlight and really showcase your lab. Invite upper administration, faculty and staff, deans, school superintendents, and special education directors. Don't forget to include your state department of education, local school systems (professional development directors) and local business. Anyone you think that would be interested. The director personally hand delivered invitations to upper administration and deans. Your agenda should include a short welcome and then two simulations (each lasting around 5-6 minutes each). Call for volunteers from the floor. The best simulations are done impromptu, that way participants do not get nervous or try and think ahead about what they would say and do. Keep it authentic. Question and answer sessions will take up much of your time, and that is ok...you want it to. Having participants brainstorm on how to use your lab increases the likelihood they will pay to use it.

Customizing the logistics of your laboratory (the who, what, when, and where)

Why should I customize the logistics of my lab? Keeping organized and prompt is key in a successful lab. There are certain steps to signing up for and using the lab. Faculty must pass the “Facilitator Handbook Quiz” before being allowed to use the lab. First, facilitators must read the “Facilitator Handbook,” and watch the “Facilitator Handbook Video”. Then, they must pass a “Facilitator Quiz.” After they pass the quiz, they are given a link to a university wide calendar to sign up for simulation design times or simulations (Qualtrics survey). The calendar will then send automated emails to the director and the simulation specialist to ensure it is on our personal calendars. Other facilitators can also see what times are still available to sign up for when perusing the university calendar. The automated email also helps aid in keeping up with hourly pay. Next, the facilitator completes the “Simulation Design Form.” This form allows for the facilitator to write out the needs of the scenario, including; title, simulation goal(s), scenario design description, specific quotes, number of pushbacks, and resolution. Facilitators can bring additional information to the meeting with the simulation specialist. Additional information includes content area information, for example, a synopsis of Dracula, or a refresher on the water cycle. Information to help support the simulation specialist in acting out your desired scene. As the director, I also made a short video on “how to” open up and start the VAL. I meet every first-time facilitator in the VAL to ensure they understand how everything gets started during their simulation. After that, facilitators are on their own and seem to do well. Instructions on how to get going in the VAL are sent via email, in a handout, and on our private COE webpage. The university Instructional Technology (IT) numbers and *Mursion* helpline are also laminated in the VAL.

Creating forms and questionnaires

Why should I have forms and questionnaires for my lab? Forms and questionnaires are a great way to keep your lab organized and allows you to continue with other teaching and university duties. Qualtrics sends email alerts whenever one is completed that way I can follow up on any issues and talk specifically with facilitators with what they are planning. It keeps me, as the director, in the loop and involved with all things VAL.

Time logs and pay are due at the end of the month. All invoices will be sent then and are double checked against the university calendar and simulation specialist time sheet. Every effort has been made to minimize the logistical needs of the grant to focus on relevant research produced in the VAL, along with my regular teaching and university wide responsibilities.

IPads are also available in the VAL with preloaded research surveys (IRB approved) for participants to complete when they are finished with a simulation. This survey is also on the COE webpage and sent out in an email to forward to students if they did not get a chance to complete it during a simulation. Again, making it easier to collect research data.

Final Thoughts

As with any lab, being organized and strategic in your planning is important. Develop your niche and tie it to university wide goals. Work on getting others involved and invite them to see classes working through live simulations. Make your job easier by making forms and information accessible and easy to understand. Remember, not all faculty will be on board, and that is ok! Sometimes technology is scary for digital immigrants and they need extra assurance. And always remain flexible...you never know when WIFI will be down or an important visitor will pop in. Being flexible will keep you calm and resilient...remember, there is no need for bells and whistles, the technology and experience sells itself. Remain true to your goal of improving and enhancing teacher practices and you cannot go wrong.

References

Abernathy, Andrew. (2014) Digital avatars allow Ole Miss students to gain hands-on teaching experience. *Alumni Review, Summer 2014, 31-34.*

Allsopp, David H., DeMarie, D., Alvarez-McHatton, P., Doone, E. (2006) Bridging the Gap between Theory and Practice: Connecting Courses with Field Experiences. *Teacher Education Quarterly, 33.1, 19-35.*

Ericsson, K. A., & And, O. (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance. *Psychological Review, 100(3), 363-406*.

Dieker, L. A., Hughes, C. E., Hynes, M. C., & Straub, C. (2017). Using simulated virtual environments to improve teacher performance. *School University Partnerships (Journal of the National Association for Professional Development Schools): Special Issue: Technology to Enhance PDS,* 10(3), 62-81.

Garland, K.V., Vasquez, E., and Pearl, C. (2012). Efficacy of Individualized Clinical in a Virtual Reality Classroom for Increasing Teachers' Fidelity of Implementation of Discrete Trial Teaching. *Education and Training in Autism and Developmental Disabilities, 47*, (4), 502-515.

Moore, Rita (2003). Reexamining the Field Experiences of Preservice Teachers. *Journal of Teacher Education 54.1: 31-42.*

Mursion Inc. Reinventing the Way Professionals Master Their Craft. TLE TeachLivE Lab.

U.S. Department of Education, Office of Special Education and Programs. (2009). 2009 Part B Child Count, students ages 6-21, 50 States, DC, PR, BIE schools.

U.S. Department of Education, Office of Postsecondary Education (2015).Teacher Shortage Areas Nationwide Listing 1990-1991 through 2015-2016.

SECTION 3
SCIENCE EDUCATION

Competency-Based Education in Science Teacher Education: The Next Disruptive Innovation or the Next Disruption?

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Introduction

Although competency-based education (CBE) is prominent mostly in medical and allied health, the scrutiny of colleges of education could have some looking for CBE as a solution to funding issues. As accreditation and ranking become increasingly more prominent and important in marketing education programs, CBE will likely be a focus for institutions. We looked into syllabi gathered from the Association and Science Teacher Education syllabus-sharing forum and cursory online searches for science teaching methods courses from over 100 institutions and aligned the most common topics with both Interstate Teacher Assessment and Support Consortium (InTASC) and National Science Teacher Association (NSTA) standards to see if common competencies in fact exist.

With more than 400 colleges and universities exploring CBE, mostly technology enabled, science teacher education is primed for joining this new paradigm. Budget models that rely heavily on student tuition drive some parts of this newfound interest, and career switchers who have worked outside of education in their respective discipline but decided to become science teachers with some practical life and job skills drive other parts of it. Those students generally want the path of least resistance to getting certified to teach so they can move into full time employment as quickly as possible. Couple this with the influx of first-generation college students who generally do not have the means to pay for a full degree while having states and banks continually limiting access to college tuition funds and the need for CBE becomes a conversation worth having in our profession. Just over 62% of college graduates are employed in positions that require a bachelor's degree, while only 27% of college graduates worked in positions that corresponded to their undergraduate degree (Abel & Deitz, 2013). With that, how important are degrees to students? Are skills/competencies really what they desire now?

Detractors to CBE state that students will not experience the complete intellectual development that a traditional student might get at a college/university (Neem, 2013). Moreover, those pushing against CBE would say that students in CBE programs don't get the faculty face time that traditional students get, which also detracts from the quality of the experience for both teacher and student. Others would argue that CBE is solely workforce driven and thus lowers the quality of education (Prince, 2015). Many science teacher education programs are, in a sense, workforce driven anyway as programs are designed to teach and provide experiential platforms to students on pedagogical skills and classroom scenarios that make them classroom ready after a few courses.

In 2013, the United States Department of Education loosened the student aid rules to account for CBE. The new rules suggest allowing institutions to acquire student aid funding by creating programs that directly measure learning, not time, and where students can matriculate at their own pace. The USDOE calls this direct assessment. With diversity in mind, both age and race, colleges of education need to have foresight into current trends of university student populations and the alarming statistics that follow. According to Georgetown University's Center on Education and the Workforce, 82 percent of new white enrollments have gone to the 468 most selective colleges, while 72 percent of new Hispanic enrollment and 68 percent of new African-American enrollment have gone to the two-year and four-year open-access schools since 1995. The completion rates at the latter institutions are substantially lower: 49 percent for open-access two- and four-year colleges versus 82 percent for the most selective four-year colleges (Carnevale & Strohl, 2013). The National Center for Education Statistics projects that by 2020, 42 percent of all college students will be 25 years of age or older (Hussar & Bailey, 2012). Overall, not just in science education, only 11 percent of business leaders 'strongly agree' that students have the requisite skills for the workforce, whereas 96 percent of chief academic officers believe that their institutions are 'very effective' (56 percent) or 'somewhat effective' (40 percent) at preparing students for the work world (Jaschik, 2014).

While online learning has become more popular among both traditional and nontraditional students, we have reached the age of the *non-consumer* of high education. Nearly 71 percent of U.S. college-bound students do not participate in the residential college experience (Casselman, 2013). With the unanimous passing of the bipartisan Advancing Competency-Based Education Demonstration Project Act in 2014, the U.S. Department of Education announced that it was establishing experimental sites on college campuses for competency-based education (Ed Workforce, 2014).

The most prominent area in which competency-based instruction has been used is medical education. Competency-based Medical Education (CBME) requires instructors to assess students in a robust way that more accurately determines if they are prepared. The University of Toronto created a competency-based curriculum that provides challenge to medical residents by going beyond the core competencies. The developers of this program developed a curriculum that included forming a steering committee, faculty experts, and the accreditation framework. (Iglar et al., 2013). This model of CBME development could be applied to other medical schools and possibly other fields as well as this strategy grows and reaches more students.

Competency-based education has also become important to the field of nursing as the majority of employers expect that new nursing graduates are prepared to enter the field, perform various functions, and demonstrate that they have the required skills that are necessary for providing safe care to patients (Tilley, 2008). Unfortunately, there has been a concern by employers that new nursing graduates fail to demonstrate that they are competent in their abilities to perform basic clinical tasks or that there appears to be a disconnect between their education and work competencies (Tilley, 2008). Consequently, this leads to dissatisfied employers, discouraged new graduates, and disappointed patients (Anema & McCoy, 2010; Ruth-Sahd & Grab, 2012). A potential solution to this difficulty has been the implementation of competency-based education into the field of nursing education. Competency-based education has been used in the field of nursing in various ways. In the field of nursing, student performance evaluation has been conducted using the following scales:

- Schwirian's (1978) Six-Dimension Scale for Nurse Performance (6-D Scale)
- Nurse Competence Scale (NCS) (developed by Meretoja, Leino-Kilpi, and Kaira (2004)
- Self-Evaluated Core Competencies (SECC) Scale (Hsu & Hsieh, 2009)
- Competency Inventory of Nursing Students (CINS) (Hsu & Hsieh, 2013)

These quantitative instruments have shown to demonstrate strong validity and reliability for numerous studies (Klein & Fowles, 2009; Meretoja & Leino-Kilpi, 2001; Meretoja, Leino-Kilpi, & Kaira 2004).

One of the most important areas of competency-based education is developing milestones to describe the progression of competence. Iobst and Caverzagie (2013) discussed this process as called for by the Accreditation Council for Graduate Medical Education. They stated that "to be judged competent, the trainee must possess all the required abilities being assessed in a certain context at a defined stage of education or practice and must be able to apply those abilities appropriately in routine clinical practice." Defining competencies is the first step for any education program to create meaningful change in this area.

As with any growing area in education, there are some areas that CBE has challenges. One of these is that faculty may not be sufficiently prepared to assess new competencies. In any area where teaching methods are changing, such as medical education, it is imperative that faculty are provided with development around CBME and how to properly assess students (Holmboe et al., 2011). In a program at the University of Toronto faculty are required to build individual and system-based knowledge about competency-based education and ways how they should assess their learners using a new model of teaching and learning (Iglar et al. 2013).

Evaluation of Teacher Preparation Programs

According to Allen, Coble, and Crowe (2014), only one-third of teachers are being measured on their efficacy. The difficulties can be attributed to the lack of quality data in evaluating teacher preparation programs. Additionally, there is little agreement about the knowledge and skills that graduating teachers should possess and reveal through their work in the classroom. The issue that arises is the miniscule agreement on standards, competencies, and dispositions, which occurs at the abstract level that often times these skills are not able to be observed or measured via methods that present reliability and validity (Allen, Coble, & Crowe, 2014).

Council for the Accreditation for Educator Preparation (CAEP) and Pearson (Teacher Preparation Analytics (TPA) suggested that a report be devised that would review current available research and investigate available data from 15 states, as well as emphasize programs that showed to be successful at the national, state, and programmatic levels. CAEP and Pearson also requested a report that would display gaps in data collection and data systems with the goal of suggesting recommendations for improving data collection methods in order to obtain more valid and reliable data for evaluating teacher education programs.

However, the issue is that the CAEP and TPA presented an assessment measure for evaluating effectiveness of teacher programs themselves, rather than delving deeper into how current teacher preparation programs can be enhanced by incorporating various methods of instruction, such as competency-based instruction into their curriculum. In the Teacher Preparation Analytics report presented by Allen, Coble, and Crowe (2014), four key indicators are described that measure knowledge and skills of teachers after completing teacher preparation programs. The four indicators are as follows: teachers' academic content knowledge measured by college-level assessment, teacher's pedagogical content knowledge measured by national tests, teaching skills measured by national assessments, teacher's survey results where they rate the K-12 classroom teaching preparation program that they completed (Allen, Coble, & Crowe, 2014).

Teacher Education CBE

In science teacher education, we clearly have competencies; even if that is not what we call them. Common terms, such as personalized learning or adaptive learning environments have permeated throughout the science education literature. We should preface what follows with the importance of looking at CBE with a keen eye, but to not lose sight of the rigor of traditional teaching and learning. Competencies have a unique architecture as they break learning into discrete modules that are not inextricably tied to courses or topics. Time-based courses are the main currency in traditional higher education institutions, and in general, excising a week of learning from one class and inserting it into another course in an unrelated field is nearly impossible. In an online competency-based environment, however, all learning materials are tagged and mapped. Competencies are composed of series of learning objectives, and in many cases, students can draw on resources from various subject areas to achieve their learning objectives in order to master a competency. Because learning is not broken down by subject matter, an online competency-based education provider can easily combine and stack learning modules together in different ways for various students (Weise, 2014).

Cator, Schneider, and Vanderark (2014) argue that new times require new tools and new ways of thinking about teaching and learning. One vehicle for awarding competency is through badging. Cator, Schneider, and Vanderark suggest five distinct components to the badge earner process: 1. Issuer identifies and describes the competencies he/she desires. 2. Issuer established requirements for earning micro-credential/competency. 3. Earner produces and submits artifacts that demonstrates competency and meet the requirements defined by the issuer. 4. The submitted artifacts are assessed by experts or peers. 5. Credentials are awarded and shared.

Transitioning away from seat time, in favor of a structure that creates flexibility, allows students to progress as they demonstrate mastery of academic content; regardless of time, place, or pace of learning. CBE strategies could include online and blended learning, dual enrollment and early college high schools, project-based and community-based learning, and/or credit recovery, among others. It is contended that this type of learning leads to better student engagement because the content is relevant to each student and tailored to his or her unique needs. It can also lead to better student outcomes because the pace of learning is customized to each student.

CBE supporters suggest these strategies enable students to master skills at their own pace, help to save both time and money, create multiple pathways to graduation, make better use of technology, support new staffing patterns that utilize teacher skills and interests differently, take advantage of learning opportunities outside of school hours and walls, and help identify opportunities to target interventions to meet the specific learning needs of students. Each of these presents an opportunity to achieve greater efficiency and increase productivity.

Artifact Collection

The review of existing literature in the area of competency-based instruction led us to some questions for our own research:

1. What competencies are currently being evaluated in teacher education programs?
2. How do these competencies match up with the standards provided by InTASC and NSTA?
3. How could these areas of crossover be used to incorporate CBE into teacher education programs?

We set out to collect artifacts to answer these questions and concluded with consistency among science methods courses we looked into and were able to create a more involved study than we first thought possible. The methodology used to explore these questions was qualitative in nature and was a variation on a meta-analysis. Rather than looking at existing literature, we explored existing syllabi that are used in college and university science methods courses. To obtain these, we did an Internet search of science methods syllabi that were publicly available. We also went to the Association of Science Teacher Education (ASTE) syllabus sharing session during their conference in 2016. Through these two venues, we were able to find 178 syllabi. Of those 178, we then narrowed it down to 100, by making sure that we had a representation from large doctoral granting institutions, smaller regional universities, and some historically black colleges and universities. By doing this, we were able to make sure that our sample evenly represented all types of teacher education programs, but in reality, we could have used all 178 since we found that the majority had the same competencies. It is also important to illustrate that the syllabi chosen in this work were either the first methods course offered in a series or the only methods course offered in the science teacher preparation program. Of those syllabi that were the first in a series, we looked at the other syllabi available in the program and collapsed competencies to ensure the entire program was accounted for.

We went through the 100 syllabi and coded them for competencies that the courses mentioned the students should have after completing the science methods course. We were looking for commonalities in topics, readings, and content to see if our field is, in fact, already credentialing science teachers on common competencies. We then used our coding to come up with a condensed list of competencies taught in science education courses.

What are the competencies?

Through our exploration of the syllabi from teacher education courses at 100 different colleges and universities we found that the major topics each college or university covers during a science methods classes, elementary and secondary, are consistent in nine topics/ideas.

1. **Assessment:** assessment is discussed in terms of teachers developing different types of and how to assess students appropriately as a general, special needs, ELL or gifted student.

2. **Diverse Learners:** teaching to a variety of students in the classroom and being able to scaffold a lesson is being taught along with developing a lesson plan on implementation.

3. **Nature of Science/Inquiry:** this topic includes concepts such as what is science, what science should be taught, what are problems faced with teaching science and what misconceptions do students have about science concepts before new information is taught.

4. **Higher Thinking and Questioning of students:** The benefit and purpose to questioning students and developing an environment where students can feel comfortable to ask questions. This topic also includes students questioning each other in order to collaborate and work together for information and solutions.

5. **Lesson Plan Development/Inquiry/5E:** Teachers are asked to develop a science lesson that often involves inquiry and a hands-on activity. The 5E lesson plan model is widely accepted for professional lesson planning. Teachers are typically asked to submit several lesson plans throughout the methods courses. The lesson plans are geared towards scaffolding for all students, disabilities to gifted, and the lessons should encourage life-long learning

6. **Science and Literacy/Other Disciplines:** During lesson planning, incorporating other subjects is important to methods courses. The main focus for elementary science methods classes is literacy; however, many courses simply ask for a lesson to incorporate one other discipline

7. **Safe Science Classrooms:** Creating safety audits of classroom apparatuses (i.e., eye wash, fire extinguisher, signage, etc.) and identifying student safety issues.

8. **Classroom Management:** Creating classroom seating arrangements, teacher-student proximity, and discipline procedures.

9. **Understanding the Standards:** This seems to be individualized by state. There was not much evidence that NSES or NGSS were topics in this category.

What the standards say

If we map the common competencies mentioned previously to both the InTASC and NSTA preservice science teacher SPA standards, we begin to see gaps in our current science teaching method courses. With accrediting agencies and SPAs increasing pressures for national recognition, colleges and schools of education are wrought with faculty time away from what they were trained to do. Why did those nine competencies fall out of the 100 syllabi we examined if they don't align with accreditation standards?

InTASC

Taking into account the latest Interstate Teacher Assessment and Support Consortium (InTASC) standards movement toward learning progressions, we begin to see a flow of competencies deemed important for new teachers. The InTASC standards are:

Standard #1: *Learner Development*-The teacher understands how learners grow and develop, recognizing that patterns of learning and development vary individually within and across the cognitive, linguistic, social, emotional, and physical areas, and designs and implements developmentally appropriate and challenging learning experiences.

Standard #2: *Learning Differences*- The teacher uses understanding of individual differences and diverse cultures and communities to ensure inclusive learning environments that enable each learner to meet high standards.

Standard #3: *Learning Environments*- The teacher works with others to create environments that support individual and collaborative learning, and that encourage positive social interaction, active engagement in learning, and self-motivation.

Standard #4: *Content Knowledge*- The teacher understands the central concepts, tools of inquiry, and structures of the discipline(s) he or she teaches and creates learning experiences that make these aspects of the discipline accessible and meaningful for learners to assure mastery of the content.

Standard #5: *Application of Content*- The teacher understands how to connect concepts and use differing perspectives to engage learners in critical thinking, creativity, and collaborative problem solving related to authentic local and global issues.

Standard #6: *Assessment*- The teacher understands and uses multiple methods of assessment to engage learners in their own growth, to monitor learner progress, and to guide the teacher's and learner's decision making.

Standard #7: *Planning for Instruction*- The teacher plans instruction that supports every student in meeting rigorous learning goals by drawing upon knowledge of content areas, curriculum, cross-disciplinary skills, and pedagogy, as well as knowledge of learners and the community context.

Standard #8: *Instructional Strategies*- The teacher understands and uses a variety of instructional strategies to encourage learners to develop deep understanding of content areas and their connections, and to build skills to apply knowledge in meaningful ways.

Standard #9: *Professional Learning and Ethical Practice*- The teacher engages in ongoing professional learning and uses evidence to continually evaluate his/her practice, particularly the effects of his/her choices and actions on others (learners, families, other professionals, and the community), and adapts practice to meet the needs of each learner.

Standard #10: *Leadership and Collaboration*- The teacher seeks appropriate leadership roles and opportunities to take responsibility for student learning, to collaborate with learners, families, colleagues, other school professionals, and community members to ensure learner growth, and to advance the profession.

NSTA Preservice teacher SPA standards

Table 1 illustrates the map of the InTASC standards with the following National Science Teacher Association (NSTA) preservice teacher SPA Standards. We had the authors all prepare this alignment and then compared results while coming to agreement on where the competencies align to both InTASC and NSTA standards. For your references, the newest standards are:

Standard 1. *Content*. Teachers of science understand and can articulate the knowledge and practices of contemporary science. They can interrelate and interpret important concepts, ideas, and applications in their fields of licensure; and can conduct scientific investigations. To show that they are prepared in content, teachers of science must demonstrate that they:

(a) Understand and can successfully convey to students the major concepts, principles, theories, laws, and interrelationships of their fields of licensure and supporting fields as recommended by the National Science Teachers Association;

b) Understand and can successfully convey to students the unifying concepts of science delineated by the National Science Education Standards;

(c) Understand and can successfully convey to students important personal and technological applications of science in their fields of licensure;

(d) Understand research and can successfully design, conduct, report and evaluate investigations in science;

(e) Understand and can successfully use mathematics to process and report data, and solve problems, in their field(s) of licensure.

Standard 2. *Nature of Science*. Teachers of science engage students effectively in studies of the history, philosophy, and practice of science. They enable students to distinguish science from

nonscience, understand the evolution and practice of science as a human endeavor, and critically analyze assertions made in the name of science. To show they are prepared to teach the nature of science, teachers of science must demonstrate that they:

(a) Understand the historical and cultural development of science and the evolution of knowledge in their discipline;

(b) Understand the philosophical tenets, assumptions, goals, and values that distinguish science from technology and from other ways of knowing the world;

(c) Engage students successfully in studies of the nature of science including, when possible, the critical analysis of false or doubtful assertions made in the name of science.

Standard 3. *Inquiry*. Teachers of science engage students both in studies of various methods of scientific inquiry and in active learning through scientific inquiry. They encourage students, individually and collaboratively, to observe, ask questions, design inquiries, and collect and interpret data in order to develop concepts and relationships from empirical experiences. To show that they are prepared to teach through inquiry, teachers of science must demonstrate that they:

(a) Understand the processes, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge;

(b) Engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

Standard 4. *Issues*. Teachers of science recognize that informed citizens must be prepared to make decisions and take action on contemporary science- and technology-related issues of interest to the general society. They require students to conduct inquiries into the factual basis of such issues and to assess possible actions and outcomes based upon their goals and values. To show that they are prepared to engage students in studies of issues related to science, teachers of science must demonstrate that they:

(a) Understand socially important issues related to science and technology in their field of licensure, as well as processes used to analyze and make decisions on such issues;

(b) Engage students successfully in the analysis of problems, including considerations of risks, costs, and benefits of alternative solutions; relating these to the knowledge, goals and values of the students.

Standard 5. *General Skills of Teaching*. Teachers of science create a community of diverse learners who construct meaning from their science experiences and possess a disposition for further exploration and learning. They use, and can justify, a variety of classroom arrangements, groupings, actions, strategies, and methodologies. To show that they are prepared to create a community of diverse learners, teachers of science must demonstrate that they:

(a) Vary their teaching actions, strategies, and methods to promote the development of multiple student skills and levels of understanding;

(b) Successfully promote the learning of science by students with different abilities, needs, interests, and backgrounds;

(c) Successfully organize and engage students in collaborative learning using different student group learning strategies;

(d) Successfully use technological tools, including but not limited to computer technology, to access resources, collect and process data, and facilitate the learning of science;

(e) Understand and build effectively upon the prior beliefs, knowledge, experiences, and interests of students;

(f) Create and maintain a psychologically and socially safe and supportive learning environment.

Standard 6. *Curriculum*. Teachers of science plan and implement an active, coherent, and effective curriculum that is consistent with the goals and recommendations of the National Science Education Standards. They begin with the end in mind and effectively incorporate contemporary practices and resources into their planning and teaching. To show that they are prepared to plan and implement an effective science curriculum, teachers of science must demonstrate that they:

(a) Understand the curricular recommendations of the National Science Education Standards, and can identify, access, and/or create resources and activities for science education that are consistent with the standards;

(b) Plan and implement internally consistent units of study that address the diverse goals of the National Science Education Standards and the needs and abilities of students.

Standard 7. *Science in the Community*. Teachers of science relate their discipline to their local and regional communities, involving stakeholders and using the individual, institutional, and natural resources of the community in their teaching. They actively engage students in science related studies or activities related to locally important issues. To show that they are prepared to relate science to the community, teachers of science must demonstrate that they:

(a) Identify ways to relate science to the community, involve stakeholders, and use community resources to promote the learning of science;

(b) Involve students successfully in activities that relate science to resources and stakeholders in the community or to the resolution of issues important to the community.

Standard 8. *Assessment*. Teachers of science construct and use effective assessment strategies to determine the backgrounds and achievements of learners and facilitate their intellectual, social, and personal development. They assess students fairly and equitably, and require that students engage in ongoing self-assessment. To show that they are prepared to use assessment effectively, teachers of science must demonstrate that they:

(a) Use multiple assessment tools and strategies to achieve important goals for instruction that are aligned with methods of instruction and the needs of students;

(b) Use the results of multiple assessments to guide and modify instruction, the classroom environment, or the assessment process;

(c) Use the results of assessments as vehicles for students to analyze their own learning, engaging students in reflective self-analysis of their own work.

Standard 9. *Safety and Welfare*. Teachers of science organize safe and effective learning environments that promote the success of students and the welfare of all living things. They require and promote knowledge and respect for safety, and oversee the welfare of all living things used in the classroom or found in the field. To show that they are prepared, teachers of science must demonstrate that they:

(a) Understand the legal and ethical responsibilities of science teachers for the welfare of their students, the proper treatment of animals, and the maintenance and disposal of materials.

(b) Know and practice safe and proper techniques for the preparation, storage, dispensing, supervision, and disposal of all materials used in science instruction;

(c) Know and follow emergency procedures, maintain safety equipment, and ensure safety procedures appropriate for the activities and the abilities of students;

(d) Treat all living organisms used in the classroom or found in the field in a safe, humane, and ethical manner and respect legal restrictions on their collection, keeping, and use.

Standard 10. *Professional Growth*. Teachers of science strive continuously to grow and change, personally and professionally, to meet the diverse needs of their students, school, community, and profession. They have a desire and disposition for growth and betterment. To show their disposition for growth, teachers of science must demonstrate that they:

(a) Engage actively and continuously in opportunities for professional learning and leadership that reach beyond minimum job requirements;

(b) Reflect constantly upon their teaching and identify ways and means through which they may grow professionally;

(c) Use information from students, supervisors, colleagues and others to improve their teaching and facilitate their professional growth;

(d) Interact effectively with colleagues, parents, and students; mentor new colleagues; and foster positive relationships with the community.

This map is subjective in nature and the nine competencies that fell out of our syllabi evaluation suggest there is not a clear alignment in standards to what the vast majority of the field is teaching in science teacher methods courses. It is interesting to note that an alignment with content knowledge did not show up in our syllabi, it might be because individual content areas at universities have their own standards and competencies that students have to meet usually before even entering a teacher prep program. Many science teacher education programs assume content knowledge before admission to their program. This was not always the case as we did find some syllabi that provided content-based courses in a pedagogical content knowledge setting but overall, it was not a common enough theme to fall out in our review.

Table 1. Map of InTASC, NSTA, and Common Competencies

InTASC Principles	NSTA Preservice SPA	Common Syllabi competencies
Standard 1 (Learner development)	Standard 5 (General Skills of Teaching), 10 (Professional Growth)	Diverse learners
Standard 2 (Learning differences)	Standard 5 (General Skills of Teaching), 6 (Curriculum)	Diverse learners
Standard 3 (Learning environments)	Standard 10 (Professional Growth)	Science & Literacy
Standard 4 (Content knowledge)	Standard 1 (Content)	
Standard 5 (Application of content)	Standard 2 (NOS), Standard 4 (Issues), Standard 5 (General Skills of Teaching)	NOS
Standard 6 (Assessment)	Standard 8 (Assessment)	Assessment
Standard 7 (Planning for instruction)	Standard 6 (Curriculum)	Management, Lesson planning
Standard 8 (Instructional strategies)	Standard 3 (Inquiry), 5 (General Skills of Teaching), Standard 7 (Science in the community)	Higher order thinking & Questioning, Lesson planning
Standard 9 (Professional learning and ethical practice)	Standard 9 (Safety & Welfare)	Safety, Understanding the standards
Standard 10 (Leadership & Collaboration)	Standard 7 (Science in the community), Standard 10 (Professional Growth)	Science & Literacy/Other disciplines

Implications

Although the push for CBE is arguably eminent, it does not come without its concerns and how it fits into the current budget and effort models in colleges and universities. For example, CBE doesn't fit the traditional semester model. If a student completes and shows competency on a given topic/theme, then that student is ready to move on to the next competency regardless of how long it takes him/her to show competence. Cohorts will be a thing of the past so admission, course scheduling, scope and sequence models will need to be revised. Colleges and universities need to change teaching load equations to fit competency experiences rather than full time equivalents (FTE). This has implications for retention, promotion, and tenure models.

In many degree programs, it is difficult to truly articulate what the degrees means and how that degree prepares students for the workforce. In science teacher education, our research base begins to tell programs what is important but relating that to practice is often the challenge. Along with standards and accrediting agencies, employer input is very important as we design competencies and the subsequent programs. Continual re-evaluation of the competencies and how we teach and assess said competencies is critical. Relationships with school systems is also very important to keep lines of communication open and an advisory panel that continually articulates what their needs might be to colleges and universities what school system needs.

Much of the CBE literature has a strong technology driven component to it. Programs that boast CBE success are technology driven and have a strong online presence. For example, UW Madison's 'flexible option' provides CBE degrees and has an average student age of 37.5. Assessment is crucial and with student working at their own pace, often working full time jobs, creating valid and reliable assessments might be more easily accomplished through technological means. Data management, enrollment, admissions, etc. are logistical concerns in CBE so technological solutions might be the most cost effective way to counter these issues. In the recent past Massive Open Online Courses (MOOCs) were to be the next great disruptive innovation in education. MOOCs promised to be the CBE vehicle of the 21st century but most would argue that MOOCS have failed and are clearly not the answer. The business model doesn't support them nor do the faculty or student completion and satisfaction models. The amalgam of workforce education, competency based learning, and online learning might be the secret sauce to reaching the non-consumers of higher education. The interesting, and maybe concerning irony is that technology integration into science teaching is not a competency that was common in the syllabi review. Maybe this is because teacher education programs rely on education technologies classes to cover that competency but it has been argued by many (Author, 2017) that discipline specific technology integration is most powerful.

Where do we go from here? It is our hope that this article begins the conversation in science teacher education that will propel our profession forward as CBE challenges come about. As we being this conversation, we can look to Cator, Schneider and Vander Ark (2014) suggestion on the four pillars of teacher professional development in a CBE environment:

1. Some element of teacher control over time, place, path, and/or pace
2. Balance between teacher-defined goals, goals as defined by administration through teacher evaluation efforts, and school and district educational goals
3. Job-embedded and meaningful integration into the classroom practice
4. Competency-based progression

Former U.S. Secretary of Education Arne Duncan said, "At a time when college matters more than ever, we have to provide **a flexible, innovative experience** that can meet the needs of every American." The time is now for science teacher education to look at the competencies we are all teaching, align them with the standards and principles of our accrediting agencies, and attract more students to work toward classroom ready skill sets in a time efficient and cost effective manner. Will this process be disruptive? Probably, but if it is a disruptive innovation than we have set up the next generation of science learners with teachers that are highly qualified and not in terrible debt.

References

Abel, J.R., & Deitz, R. (2013). Do big cities help college graduates find better jobs? http://libertystreeteconomics.newyorkfed.org/2013/05/do-big-cities-help-college-graduates-find-better-jobs.html#.V30X25MrJE6. Accessed March 20, 2016

Allen, M., Coble, C., & Crowe, E. (2014). Building an Evidence-Based System for Teacher Preparation. *Washington, DC: CAEP. Retrieved March*, *2, 2017.*

Anema, M. G., & McCoy, J. (2010). *Competency-based nursing education: Guide to achieving outstanding learner outcomes*. Springer Publishing Company, NY.

Calman, L. (2006). Patients' views of nurses' competence. *Nurse Education Today, 26*, 719-725.

Carnevale, A.P., & Strohl, J. (2013). Separate and Unequal: How Higher Education Reinforces the Intergenerational Reproduction of White Racial Privilege. Georgetown University, Georgetown Public Policy Institute, Center on Education and the Workforce (July), 9, 11, 16.

Casselman, B. (2013). Number of the Week: 'Non-Traditional' Students Are Majority on College Campuses. *Wall Street Journal*, July 6.

Cator, K., Schneider, C., & Vanderark, T. (2014). Preparing teachers for deeper learning. http://gettingsmart.com/wp-content/uploads/2014/01/FINAL-Preparing-Teachers-for-Deeper-Learning-Paper.pdf. Accessed August 4, 2016

Coutinho, S. (2008). Self-efficacy, metacognition, and performance. *North American Journal of Psychology, 10*(1), 165-172.

Hill, L. H., & Kirkwood, C. (2005). Student and preceptor perception of performance in advanced pharmacy practice experiences. *American Journal of Pharmaceutical Education, 69*(4), 467-474.

Holmboe, E. S., Ward, D. S., Reznick, R. K., Katsufrakis, P. J., Leslie, K. M., Patel, V. L., Nelson, E. A. (2011). Faculty Development in Assessment: The Missing Link in Competency-Based Medical Education: Academic Medicine, 86(4), 460–467. doi:10.1097/ACM.0b013e31820cb2a7

Hsu, L. L. (2010). Metacognitive inventory for nursing students in Taiwan: Instrument development and testing. *Journal of Advanced Nursing, 66*(11), 2573-2581.

Hsu, L.L., & Hsieh, S. I. (2009). Testing of a measurement model for baccalaureate nursing students' self-evaluation of core competencies. *Journal of Advanced Nursing, 65*(11), 2454-2463.

Hsu, L.L., & Hsieh, S. I. (2013). Development and psychometric evaluation of the competency inventory for nursing students: A learning outcome perspective. *Nurse Education Today, 33*(5), 492-497.

Hussar, W.J. & Bailey, T.M. (2011). Projections of Education Statistics to 2020 (NCES 2011-026), U.S. Department of Education, National Center for Education Statistics (Washington, DC: U.S. Government Printing Office, 2011), cited in Brian T. Prescott and Peace Bransberger, *Knocking at the College Door: Projections of High School Graduates,* 8th ed. (Boulder, CO: Western Interstate Commission for Higher Education, 2012), 2.

Iglar, K., Whitehead, C., & Takahashi, S. G. (2013). Competency-based education in family medicine. Medical Teacher, 35(2), 115–119. doi:10.3109/0142159X.2012.733837

Iobst, W. F., & Caverzagie, K. J. (2013). Milestones and Competency-Based Medical Education. Gastroenterology, 145(5), 921–924. doi:10.1053/j.gastro.2013.09.029

Jaschik, S. (2014). Pressure on the Provosts: 2014 Survey of Chief Academic Officers. *Inside Higher Ed,* January 23. https://www.insidehighered.com/news/survey/pressure-provosts-2014-survey-chief-academic-officers

Klein, C. J., & Fowles, E. R. (2009). An investigation of nursing competence and the competency outcomes performance assessment curricular approach: Senior students' self-reported perceptions. *Journal of Professional Nursing, 25*(2), 109-121.

Martinez, M. D. (2006). What is metacognition? *Phi Delta Kappan, 87*(9), 696-699.

Meretoja, R., Leino-Kilpi, H. (2001). Instruments for evaluating nurse competence. *Journal of Nursing Administration, 31*(7-8), 346-352.

Meretoja, R., Leino-Kilpi, H., & Kaira, A. M. (2004). Comparison of nurse competence in different hospital work environments. *Journal of Nursing Management, 12*(5), 329-336.

Neem, J.N. (2013). Experience matters: Why competency-based education will not replace seat time. https://www.aacu.org/liberaleducation/2013/fall/neem. Accessed February 24, 2016

Pijl-Zieber, E. M., Barton, S., Konkin, J., Awosoga, O., & Caineet, V. (2013). Competence and competency-based nursing education: Finding our way through the issues. *Nurse Education Today, 34*, 676-678.

Quirk, M. (2006). *Intuition and metacognition in medical education: Keys to developing expertise*. Springer, New York, NY.

Prince, H.J. (2015). Connecting workers to credentials: The promise and pitfalls of awarding academic credit for prior learning. In C.V. Horn, T. Edwards, & T. Greene (Eds). Transforming U.S. workforce development policies for the 21st century.

Ruth-Sahd, L. A., & Grab, C. J. (2012). And this, too, has already changed in nursing. *Journal of Lancaster General Hospital, 7*(2), 83-88.

Schwirian, P. M. (1978). Evaluating the performance of nurses: A multidimensional approach. *Nursing Research, 27*(6), 347-351.

Sigler, E. A., & Tallent-Runnels, M. K. (2006). Critical thinking in nursing education: Literature review. *Journal of General Psychology, 133*(3), 257-276.

Thomas, G. P., & McRobbie, C. J. (2001). Using a metaphor for learning to improve students' metacognition in the chemistry classroom. *Journal of Research in Science Teaching, 38*(2), 222-259.

Tilley, D. S. (2008). Competency in nursing: A concept analysis. *Journal of Continuing Education in Nursing, 39*(2), 58-64.

Weise, M.R. (2014). Got skills? Why online competency-based education is the disruptive innovation in high education. E*DUCAUSE Review,* vol. 49, no. 6 (November/ December 2014)

West, M. M., Bross, G., Snyder, M. (2007). Teaching complex trauma care in a curriculum challenges critical thinking and clinical judgement-how nurses can help. *Journal of Trauma Nursing, 14*(3), 131-135.

Historical Development of Laboratory in the Elementary School Science Program in Turkey

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Introduction

Nowadays the science can be defined as the process of perceiving and recognizing the natural world, studying natural phenomena, thinking about the nature of knowledge, accumulation of knowledge and obtaining information, reaching new information by making use of existing knowledge, and making predictions about events that have not yet been observed. Science has an important place in the development and economic achievement of countries. The race in the world of science and technology has increased the importance of science education. Therefore, countries aim to educate individuals who can produce knowledge and technology to ensure the continuity of progress in scientific and technological developments. In this context, various attempts have been made to improve the quality of science education in the last century. As a result, new curricula have been developed in accordance with the changes in science. Such initiatives which are made to ensure that the educational programs are at the desired level are of great importance for the development of countries. Today the developments in the field of science and technology necessitate the continuous development of the educational program and continuous researches related to this field. Examining the educational programs developed in our country and revealing the mistakes made in the past are important in order to avoid future failures in the development of educational programs. In this context, the review of science education programs, which have been developed to date, in terms of planning, implementation and evaluation stages is especially important in terms of shedding light on the development of future science programs.

The development of science programs in Turkey from the proclamation of the Republic to the present is examined. Science programs in this historical process are discussed in terms of laboratory use. In the preparation of new science programs, it is necessary to reveal missing or incorrect applications determined in previous programs.

Development of science education programs in Turkey

In parallel to the economic, social, political etc. advances and developments in the world, the educational systems of the developing countries are being changed which are directly reflected in their educational programs. As in other countries in the world in Turkey many changes and improvements have been made in the educational programs beginning by the proclamation of the Republic. The innovations and improvements are also made in the science education programs. Such changes have been made for the science education programs for all levels, including primary schools, secondary schools and high schools. In addition, the goals and major contents of the programs are continuously revised. More specifically, the science programs have been revised in the years of 1924, 1926, 1936, 1948, 1968, 1982, 1992 and 2000 (Gürdal ve Önen, 2010 cited in Ersoy, 2013). In 2004 the ministry of national education (MONE) made changes in the educational programs of the primary school courses including Turkish language, mathematics, life sciences, social studies and science and technology (Gömleksiz and Bulut, 2006).

In 2012 a new system for primary and secondary education in Turkey was initiated which is called 4+4+4. Based on this change beginning by 2012 - 2013 school year the educational programs were revised (MONE, 2012). That for science education program was finalized in 2013. It covered the changes for the grades of 3, 4, 5, 6, 7 and 8 (MONE, 2013). The education program was updated in 2018 for these grades (MONE, 2018).

For the science courses there have been eight education programs in Turkey which were developed in the years of 1924, 1926, 1936, 1948, 1968, 2004, 2013 and 2018. These educational programs are discussed below.

First School Education Program (1924)

Following the proclamation of the Republic a new education system was developed. With the law on unification of education called Tevhid-i Tedrisat, which was enacted in 1924 all education institutions were attached to the Ministry of National Education, and the educational programs for all courses were changed (Gözütok, 2003). In the 1924 program there were no stated goals for the courses in a systematical way. Instead, the goals were expressed in different parts of the education program like the goals of other courses. Science course was named as Nature Inspection, Agriculture and Hygiene and was offered three hours per week for the grades 1 and 2 and two hours per week for the grades of 3, 4 and 5. During the Ottoman state the primary education had lasted for six years which was altered to five years. Figure 1 shows the weekly schedule for the course of nature inspection, agriculture and hygiene for the boys' only primary school grades (First school education program, 1924).

Table 1. Weekly Schedule for the Course of Nature Inspection, Agriculture and Hygiene for Primary School

COURSE	1. grade	2. grade	3. grade	4. grade	5. grade
Nature Inspection, Agriculture and Hygiene	3	3	2	2	2

1926 Program:

The 1926 education program is based on Dewey's concepts of "Life Science, collective school and business school" (Wilson and Başgöz, 1973). "In the former education programs the courses were regarded as independent study subjects, and the relationships among them were not emphasized. In recent programs such relationships are frequently taken into consideration and emphasized. It is accepted that all courses should be delivered adopting a collective education approach. Although the courses such as "nature inspection", "social studies", "history" and "geography" were delivered separately in the old education programs, in the new education program these courses are grouped under the course of "Life Sciences" for the first level education. This course will be the backbone of the education system and other courses will be rest on it" (First school education program, 1930). The science course was still named as Nature Inspection, Agriculture and Hygiene, and also, was offered three hours per week for the grades 1 and 2 and two hours per week for the grades of 3, 4 and 5.

The weekly schedule for the course of nature inspection, agriculture and hygiene in the 1926 program is given in Table 2 (MONE, 1926):

Table 2. Weekly Schedule for the Course of Nature Inspection, Agriculture and Hygiene for Primary School

COURSES	1. grade	2. grade	3. grade	4. grade	5. grade
Nature inspection, agriculture and hygiene	3	3	2	2	2

1936 Program

The 1936 education program had significant changes. During this period the revolutions were completed and in use. Therefore, the program fully represented the views of the state on the educational topics. Hence, the 1936 education program is very significant (Kıncal, 1993). In contrast to the 1926 education program the new one had much clearer and plain structure. All expressions about teaching and education were consistent with the premises of educational sciences. In the program the course of life sciences covered the topics related to science for the first level (the first three grades) and such topics were included in the course of "Nature Knowledge" which was delivered to the grades of 4 and 5 for three hours per week.

Table 3. Weekly Schedule for the Course of Life Sciences and Nature Knowledge in the 1936 Education Program

COURSES	1. grade	2. grade	3. grade	4. grade	5. grade
Nature Knowledge	-	-	-	3	3
Life Sciences	5	6	7		

1948 Program

In 1946 Turkey adopted a multi political party system which required the adoption of a democratic education. In order to meet this requirement in 1948 a new education program was developed (Binbaşıoğlu, 1995). In the 1948 education program the goals of each courses were explained and given in terms of the expected teacher behaviors. These statements were expressed in the form of general aims. The program also included the subject list and the teaching materials and equipment for each course. It also covered the basic reasons for taking the courses. Although a separate section for the evaluation was included in the program it was explained through some clues (Tazebay et. al., 2000). The program also included the major goals of national education in terms of “social, personal, interpersonal relations and economical life” (Binbaşıoğlu, 1995). The weekly schedule for the course of natural knowledge included in the 1948 education program is given in Table 4:

Table 4. Weekly Schedule for the Course of Natural Knowledge Included in the 1948 Education Program

COURSES	1. grade	2. grade	3. grade	4. grade	5. grade
Natural Knowledge- Family Knowledge-Agriculture-Business	-	-	-	3	3
Life sciences	5	6	7		

In the 1948 education program the science topics were given under the name of “life sciences” for the first, second and third grades and were covered under the courses of “natural knowledge”, “family knowledge” and “Agriculture-Work” for the fourth and fifth grades. In the program it was assumed that “the course of life sciences is a course of observation, experience and practice” and that “this course attempts to make students comprehend the natural and social facts in consistent with their mental development.”

1968 Program

Like in the 1948 science education program in the program which was developed in 1968 science-related topics were covered in the course of life sciences for primary students. In the program the following definition was given for the course: “the course is one which is dependent on observation, practice and experiment” which makes it a science course. In the 1968 primary education program, the course was named as “science and natural sciences” which was a combined version of the natural knowledge, agriculture-work and family knowledge. One of the most distinctive feature of the course, science and natural sciences was that the topics taught were regarded as a whole in terms of knowledge and understanding. The program followed the “unite approach”. It did not cover an analysis of goals-behavior. An active student participation was recommended. The weekly schedule for the course of science and natural knowledge included in the 1968 education program is given in Table 5:

Table 5. Weekly Schedule for the Course Science and Natural Knowledge Included in the 1948 Education Program

COURSES	1. grade	2. grade	3. grade	4. grade	5. grade
Science and Natural Knowledge	-	-	-	4	4

The goals of the science and natural knowledge course covered in the 1968 education program were to introduce students the environment in which they live and to make them in harmony with it. The program aimed to educate the children in the home and family life as individuals who were familiar with the environment and who were able to meet their needs and help themselves in their environment. In order to achieve these aims the program considered children to be taught the knowledge of science more intensively. This program, which paid much more importance to observation rather than experiments, to knowledge rather than practice and to memorize the content rather than thinking, researching, practicing and questioning it. It was a teacher-centered program and failed to provide an active student participation. The science and natural knowledge program developed in 1968 was revised both in 1974 and in 1977. As result of these revisions the course was renamed as “science”, and some content of the units were changed. Çilenti argued that the program put emphasize on the philosophy of social benefits and technology and on the principle of transmitting knowledge to students through scientific process. There were no independent science courses in the first three classes of primary schools. Some science subjects were included in the life science courses in these grades. In the life sciences programs instead of scientific methods to be used in teaching science-related topics the premises of social benefits were emphasized.

In 1992 science education program, the laboratory method began to be used in the courses which was not covered in the science education program of 1968. The aim was to present students the experimental dimensions of the topics and concepts taught. It was thought that learning experience in laboratories would facilitate the understanding and learning of the topics by students. The program of 1992 also stated that the interaction between human beings and their environment is mutual. Both the positive or negative impact of the environment on human beings and the benefit or harm to the environment by human beings are of great importance in this interaction. It was also thought that presenting this knowledge to the student within the framework of science courses would enable them to understand the causes and consequences of human-environment interaction and cause them to become aware of their behavior in relation to environment. This program seems to be much more comprehensive than the 1968 program. But it still emphasized the teaching of the content and this was leading to its failure to teach science taking into consideration its environment dimension.

The science education program developed in 2000 aimed to train individuals who were actively interested in their environment and the world, were able to generate reasonable questions and to collect and analyze the data through experiments, to report their information using appropriate ways, who are responsible, knowledgeable and science literate. It adopted *the constructivist method* and it was developed as a student-centered program. The program was totally different from all science education programs developed until that period. This program was designed to maximize student participation by making them more active, to make teachers to assume the role of a guide and, above all, to learn the content by students' own effort and participation.

In the science program which was put in use in 2005 the approach of "producing science literate citizens" was adopted. It was developed based on the constructivist approach. The task of teachers is not to transmit the information in the textbooks to students, but to guide them to make them as active participants of their learning. This approach assumes that learning is a totally individual activity. Individuals can learn what they want using their own method whenever they want. This program was student-centered and supports the idea that students learn by doing, experiencing and thinking about. Therefore, basic approaches related to the teaching and learning process and evaluation process of the fourth and fifth grade science and technology courses of the 2005 program were completely different from the previous approaches adopted.

The weekly schedule of the science and technology courses of the 2005 program are given in Table 6a and 6b:

Table 6a. Weekly Schedule for the Course of Science and Teachnology for Primary Grades

COURSES	1. grade	2. grade	3. grade	4. grade	5. grade
Science and technology	-	-	-	3	3

Table 6b. Weekly Schedule for the Course of Science and Technology for Secondary Grades

COURSES	6. grade	7. grade	8. grade
Science and technology	4	4	4

The major focus of the program can be stated as follows (MONE, 2005):

- Instead of supporting memorization a new perspective was proposed in which skills and understand were improved and which is based on reasoning. It is aimed to train students who are searching, questioning, examining, critically thinking and making decisions independently.
- It is proposed to give the basic information required in the student's life instead of intense knowledge transfer. Students would obtain this information as a result of their own experiences.

- A student-centered teaching approach was adopted instead of a teacher centered teaching approach which aims at giving information to students. Teachers are just a guide.
- It is proposed to emphasize individual differences of students. Students in a classroom have different individual characteristics and different abilities. They all have a different mental and emotional world. It is aimed that these differences will be emphasized and everyone will learn by experiencing and doing.
- The program content is based on a spiral approach. Therefore, the basic concepts are discussed in each class. However, as the upper classes were passed, the depth of the gains increased and the scope expanded.

Given that the major goal of the science and technology course is not just to provide information to the students, there are seven learning domains which all support the science and technology literacy. Four of them are "Living Beings and Life, Matter and Phase, Physical Events, Earth and Universe". These are about basic science concepts and principles. There are three more learning domains which are directly related to science and technology literacy: Scientific Process Skills, Science-Technology-Society-Environment, Attitudes and Values (MONE, 2005).

In 2012 the educational system of Turkey was modified and it was called 4+4+4 system. In parallel to this change the education programs began to be updated from 2012 - 2013 (MONE, 2012). The education program for science courses was developed in 2013 in consistent with this change. The revised program addressed the grades of 3, 4, 5, 6, 7 and 8 (MONE, 2013). In February 2013 the board of education and discipline of the MONE passed a new regulation naming the course as science course which was first delivered to the fifth grade students from the school year of 2013-2014 and which was delivered to the third grade students from the school year of 2014-2015. The weekly class hours for the 3rd and 4th grades are 3 and for the 5th and 8ht grades is 4 (MONE-TTKB, 2013b). Table 7a and 7b show the weekly schedule for the science courses for primary grades and secondary grades as stated in the 2012 education program.

Table 7 a. Weekly Schedule for the Course Science for Primary Grades

COURSES	1. grade	2. grade	3. grade	4. grade
Science	-	-	3	3

Table 7 b. Weekly Schedule for the Course Science for Secondary Grades

COURSES	5. grade	6. grade	7. grade	8. grade
Science	4	4	4	4

In the 2018 science education program (which addresses the grades of 3, 4, 5, 6, 7 and 8) the interdisciplinary inquiry based learning approach adopted (MONE 2018). A holistic perspective has been adopted in the newly accepted science education program in terms of learning-teaching theories and practices. It is generally dependent on a learning strategy which supports the responsibility of students for their learning and active student participation. This strategy specifically relies on inquiry based learning and the transfer of knowledge. In this process, students undertake the role of the individual who investigates, questions, explains, discusses and transforms the source of knowledge while teachers assume the role of encouraging and guiding. It is aimed to integrate science with mathematics, technology and engineering and to make students investigate the problems from an interdisciplinary point of view. In this context, the primary role of teachers is to provide the students with the guidance to integrate science, technology, engineering and mathematics to reach their potential level of higher-order thinking, product development, invention and innovation. Teachers are the guides who share the value and importance of the science and the responsibility and excitement of achieving scientific knowledge with their students and also direct the research process in their class. Teachers encourage the students to develop the spirit and emotion of research and the scientific way of thinking and encourage them to adopt universal values of ethics, national and cultural values, and scientific ethics in practice. Students will be able to communicate and collaborate effectively with their peers when they investigate the information.

Field specific skills are included in the Science Course Curriculum published in 2018 are as follows:

a) Scientific Process Skills

b) Life Skills (Analytical Thinking, Decision Making, Creative Thinking,

Entrepreneurship, Communication, Team work)

c) Engineering and Design Skills (Innovative thinking)

According to the 2018 science education program, the weekly science course schedules in the primary and secondary Schools are shown in Table 8a and Table 8b:

Table 8a. Weekly Science Courses of Primary Schools

COURSE	1. grade	2. grade	3. grade	4. grade
Science	-	-	3	3

Table 8b. Weekly Science Courses of Secondary Schools

COURSES	5. grade	6. grade	7. grade	8. grade
Science	4	4	4	4

An analysis of the science education programs in terms of activity patterns

The 1968 science education program did not include any information about experiments and teaching activities During the lessons, what activities would be done was left to the teacher. The units covered some problems related to the subjects. Teachers were asked to make observations and experiments on these problems. In the program, it is stated that experiments and observations should be done in three ways (continuous, when needed and immediately) and the explanations about the activities are given as follows:

1. Each unit should be introduced with an interesting problem to ensure that the students work on their own. The topics should be prepared in advance.

2. Students who have acquired a certain level of knowledge and skills should be given homework in advance for examinations, observation and experiments. They should collect information about the topics assigned and bring it to the class.

3. The summary of the subjects covered in this course should be written by students. Children should enrich them as much as possible by making drafts, sketches, graphics, cut pictures, and flat samples and use them in the collections that they will be asked to prepare.

4. These studies should be carried out in the garden of application in order to ensure that the agricultural studies covered in the Science and Natural Knowledge are taught and learned in the desired way.

5. In their work, the teacher should benefit not only from his / her knowledge and skills but also from the people in the immediate environments who have the best and most advanced knowledge, and s/he should make it possible to get help from them.

When we look at the activity descriptions given in the program, it is seen that there is not so much room for both research and questioning. Providing students with a certain knowledge and skill instead of all students reduces the participation of students in the course.

The laboratory dimension was added to the activities with the 1992 program. Therefore, students would have a chance to learn by experiencing the concepts and the unit title. The students would be able to record the findings of the laboratory studies, the results of their observations and would have information and experience about the use of the data. In addition, they would comprehend the significance of using equipment and tools and their skills would be improved. They would also comprehend the importance of studying in a planned way and have an ability to plan their studies. The activities included in the 1992 program were designed from the activities covered in the 1968 program. Here all experimental processes are discussed in detail. Those students who dealt with the process of hypothesis development and testing; identifying and controlling variables; identification; model creation; experiment editing would both observe teacher and do themselves. Therefore, they would better comprehend the problem. Students were more actively involved in the teaching and learning activities of the 1992 science education program than those of the 1968 science education program. However, the activities covered in this program were mostly science-based.

The activities included in the 2000 science education program were somewhat different from those included in the 1992 science education program in that these activities began to emphasize technological topics in addition to science related ones. The teaching and learning activities were included in the program as well as the flexibility of the teacher was left to make changes in these activities if necessary. On the other hand, the activities in this program were mostly student-centered. Students realize what they are doing as well as acquire the information themselves, and therefore, what they learn becomes permanent. In addition, different methods and techniques were adopted in this program to make all students comprehend the topics covered in the courses.

Although the Science and Technology education program which was developed in 2004 covered many innovations, it is similar to the education program which was developed in 2000. The 2004 education program adopted and followed an understanding which centered on students just like the 2000 education program. As can be seen in the pre-1992 educational programs, the educational philosophy in which the student is a passive recipient of knowledge and teacher is dominant was adopted. According to this philosophy, transferring cultural heritage to future generations constitutes the basic aim of education. In the fundamentalist philosophy of education, there is the teacher at the center of education, and the student is the passive recipient of knowledge. The information that the teacher transmits to students is certain and accurate. This information, which is memorized, aims to convey the culture of the society from generation to generation (Küçükoğlu & Bay, 2007).

The 2004 education program is based on the “constructivist approach” and the 2013 education program is dependent on the inquiry based learning approach” which is based on the constructivist approach. The vision of both programs, on the other hand, is the same. It states that the goal is to educate science literate individuals independent of their unique individual differences. The inquiry based learning approach which is based on the constructivist theory helps students develop an understanding of ”learning to learn and high-level thinking” skills (critical thinking, creative thinking, reflective thinking, analytical thinking). It allows the students to actively participate in the learning process.

Science education is a field which pays importance to experiments, observation and discoveries as well as to the questions asked by students, student research, hypotheses and their interpretation of the results (Çilenti, 1985; Odubunni & Balagun, 1991). Science education has been delivered using distinct teaching and learning methods and techniques. One of these methods is the use of laboratories by first hand in science education (Lawson, 1995; Hofstein, Nahum & Shore, 2001; Hofstein & Lunetta, 2003; Hofstein & Naaman, 2007; Kirschner & Meester 1988).

History Of Laboratory Use in Science Education

Laboratories can be regarded as places where experimental studies with various equipment and devices and analyses as well as observations are carried out. In the last century the number of laboratories increased and nearly all disciplined had their own laboratories. In Turkey almost all high and secondary schools have their physics, chemistry and biology laboratories and universities also have highly specialized versions of them.

In the USA science education was first regarded as the study of nature philosophy (Elliott, Stewart, & Lagowski, 2008). Early American leaders such as Franklin and Jefferson partly emphasized the significance of science education (Fay, 1931; Newell, 1925). Laboratory education and laboratory methods were not used in the USA until the mid-19th century. The history of laboratory education informs us about its development. Although there are chemistry laboratories both in the USA and in Europe, the use of laboratories for educational purposes originated in Germany (Good, 1936). There were education laboratories at the end of the 1700's in the USA, but the influence of German scholar Justus Von Liebig made the laboratory education much more widespread (Browne, 1941; Fay, 1931; Fife, 1975; Sheppard & Horowitz, 2006; Sheppard & Robbins, 2005).

Reforms about the improvement of science education programs in the USA soon affected the science education in Europe and similar educational activities began to be used. Such reforms covered the improvement of the contents of science and mathematics courses. Following World War I, a discussion about the necessity of laboratories for educational purposes was started. This discussion focused on the following questions: "should questions do experiments at the laboratories to learn?" and "Could students learn science only through the technique of demonstration?". Following World War II the questioning of the use of laboratories for educational purposes became uncommon. At the same time the significance of science education was again recognized. It was assumed that laboratories were one of the valid and valuable teaching methods in science education. Probable reason of these actions are significant scientific findings during war. Questions about laboratory evaluated as how is laboratory education should be. Based on these views educational programs were revised around 1960's and laboratories began to be part of these programs.

The educational programs developed in Turkey before 1992 were based on the essentialist educational philosophy. In this approach teacher is in the center of the teaching process and students are passive recipient of teaching. The knowledge transmitted by teachers is accurate and correct. It is mostly memorized by students and aims at transmitting the culture from one generation to another. The educational programs developed and implemented before 1992 did not include the laboratory work. With the use of the 1992 science education program the laboratory method began to be used unlike the 1968 science and nature education program. Thanks to this change, the students would be able to see the topics and concepts they learned in the course from an experimental aspect. The laboratory method was continued to be used in all the programs prepared later. However, it should be noted that in the 1992 science education program teachers were still at the center. The 2005 science and technology education program was developed based on the "constructivist approach". This approach assumes that teachers should be the guides of the teaching and learning process and students should be active participants of the process (MONE, 2005). The 2013 science education program was developed based on the "Inquiry-Based Learning" which is part of the constructivist approach (MONE, 2013).

In the new educational programs students were at the center of the teaching and learning process, and these programs emphasized learning through "experiencing and thinking". The current educational program which attaches importance to experiential learning and inquiring, emphasizes that permanent learning will be more in the learning environments where the individual actively participates. Experiments, observations and learning activities in which the scientific process steps are followed contribute to the development of the psycho-motor skills of individuals as well as helping to improve their high-level thinking skills. In short, the importance of laboratory practices in the application of theoretical knowledge to the practice of science, which is an applied discipline and heavily based on experiments and observations, is an undeniable fact. The new educational programs focus on the laboratory method. In last decade where scientific studies and technological developments are increasing and developing day by day, the primary aim is not to produce individuals who only consume but to train those who develop new knowledge and employ it in technological processes. Today the information production is at the highest level. Therefore, individuals should be trained to keep up with such advances and changes. In order to achieve this, it is needed to provide learning environments where experiential learning is implemented, where individuals can work freely and make decisions, and where science laboratory applications are predominant (Böyük, Demir & Erol, 2010). Laboratory practice is an integral part of science education and encourages students to questioning and scientific thinking. Laboratory applications improve students' skills such as observing, classifying, collecting data, making explanations and designing and testing experiments. These applications give students the ability to explain and interpret the events around them (Aydoğdu and Kesercioğlu, 2005). Laboratory applications have an important place in achieving the stated goals of the science courses. However, research suggests that the use of laboratory in science courses is not sufficient. For instance, the importance of laboratory activities in science courses is not emphasized enough due to following reasons; teachers' lack of adequate laboratory practices, lack of laboratory equipment and chemical materials, the idea that the experiments may be dangerous, the insufficient knowledge of waste disposal, the inability of the use of the laboratory due to the crowded classes, the inadequacy of laboratories and the large number of class sizes (Akkuş & Kadayıfçı, 2007; Kılıç, Keleş & Uzun, 2015; Çepni, Kaya, & Küçük, 2005; Aydoğdu, 1999; Demir, 2016; Aydoğdu & Şener, 2016). A number of innovations have been made in the laboratory approaches as a result of the changing educational programs. Teachers need in-service training to improve themselves in order to follow these changes and to keep up with this innovation. Therefore, it is important that teachers should be informed about innovations and changes about laboratory usage techniques and laboratory safety (Kılıç, Keleş & Uzun, 2015). Safety is the most important issue that should not be forgotten while performing any activities in the laboratory. Safety measures taken during laboratory practice should be provided not to restrict practical work, but to enable teachers and students study in a safe environment (Yılmaz & Morgil, 1999).

Accidents and Safety at School Laboratories

Laboratory work is the basis for and indispensable part of science education and all technological research. Individuals could only use their theoretical knowledge of science in laboratories which makes their learning much more permanent. Research indicates that laboratory work is necessary for successful science education, but that laboratory work is not at the desired level (Erten, 1991; Aydoğdu, 1999; Gürdal, 1991; Alpaut, 1993; Ayas et. al., 1994; Ekici, 1996). There are many factors of ineffective laboratory work. Such factors include negative school and laboratory environment, lack of necessary equipment and devices, crowded classes, teachers' lack of necessary information about teaching and learning materials and about laboratory work. Another factor contributing to underachievement in science education is related to teacher training programs, which could not produce qualified teachers (Nakiboğlu and Sarıkaya,1999; Nakiboğlu and İşbilir, 2001; Çallıca et. al., 2001; Güven et. al., 2002;

Stephenson vd., 2003; Uluçınar, Cansarar and Karaca, 2004; Kaya and Böyük, 2011; Raju, T. J. M. S., & Suryanarayana, N. V. S. 2011; Aydogdu, 2015). In addition to these difficulties there occur many accidents during the laboratory work, which cause physical injury and even death (Aydogdu, 2015; Aydoğdu, & Yardımcı, 2013; Aydoğdu, & Pekbay, 2016).

Alcohol Burst

21 Kasım 2006

At The Primary School Laboratory In Bolu A Tube Filled With Spirit Exploded During The Experimental Study Of The Fifth-Grade Students And Three Students Were Wounded.

It is reported that at Ayşe Yılmaz Becikoğlu basic education school in Doğancılar village students and their teacher İ. A. were conducting an experiment in which they were observing the power of steam resulted from boiling water. When science teacher İ.A. poured ethyl alcohol on fire alcohol tube exploded. As a result of the explosion the fifth-grade students M.İ., B.K. and D.K. were burnt and wounded. Students were taken to Bolu İzzet Baysal Hospital. Parents rushed into the hospital and wounded students said "We were conducting an experiment. Suddenly an explosion occurred. We did not understand what happened.". It is reported that they had no life-critical situation.

Source: http://www.habervitrini.com/haber.asp?id=248562-21 Kasım 2006

Tube Explosion at Science Lab, Two Students Wounded

18.12.2008

In Kazan at the science laboratory of Tahsin Şahinkaya basic education school experiment tube was exploded during the experiment. Hands of two students were wounded as a result of the explosion. They were taken to a hospital in Ankara. Kazan district governor Özlem Bozkurt Gevrek reported that they were taken there to control their situation.

Source:http://www.cnnturk.com/2008/turkiye/12/18/okulda.deney.tupu.patladi.2.yarali/505307.0/index.html-18.12.2008

Thinner Poured into Stove Killed

In 2003 a student poured thinner into the stove at the Ortadirek village basic education in Ağrı Doğubeyazıt district and it caused explosion. Although most of the students were in the garden during the explosion, the student poured thinner into the stove was killed. The school administrator who threw the can full of thinner and another person who tried to help both seriously injured in the explosion. The student poured the thinner in to the stove. The school administrator Kayalar (23), who saw the event tried to help but she was also burnt. The teacher Uysal (25) was also burnt. Another teacher Elif Tezcan broke the window to help the other students in the classroom. Injured people were taken to the hospital in Diyarbakır. However, the student died on the way to hospital.

Source:http://blog.milliyet.com.tr/yanginlar-icinde-yuregim--aysun-veburcin%20ogretmen/Blog/?BlogNo=215461

They Were Burning During Experiment

21.11.2006

The alcohol caused explosion during the experiment. In the event four students were injured. In Doğancı village basic education school in Bolu province the fifth-grade students were conducting an experiment with their teacher in the course of science and technology. The alcohol used in the experiment burst into flames. The students

Murat İpek, Burcu Koçak, Deniz Koç and İsmail Okay were injured. They were taken to theme village clinic. Then they were taken to a hospital in Bolu. Three students received outpatient treatment at the hospital. The other one treated at the ambustion service. Ten-year old Murat İpek injured from hands and face reported that they were conducting an experiment which shows how steam moves wheels. İpek reported: "We would heat the water in tubes using water. We tried to fire, but we could not manage. Finally, we did it, but the fire died down. The teacher poured alcohol on it and an explosion occurred."

Source:http://www.yenisafak.com.tr/gundem/?t=21.11.2006&q=1&c=1&i=15970&Deney/yaparken/yanıyorlardı/

Test Tube Exploded: 2 Students Wounded

09.12.2011

Experiment tubes used in the experiment in Yüzüncü Yıl Atatürk basic education school in Kocaali exploded. Two students were wounded and taken to the hospital. The sixth-grade students Mert Erkan K. and Furkan T. were conducting an experiment in the course of technology and design. During the experiment, experiment tubes exploded due to the student mistake. They were taken to the hospital. Furkan T. received an outpatient treatment, but Mert Erkan K. İs still at the hospital. The father of Mert Erkan K. Özgür K. reported that the explosion occurred during the experiment.

Source: takvim.com.tr /09.12.2011

Unfortunate Accident in School Lab

21 November 2015

*Ten students wounded in the acid-caused explosion at chemistry lab of a private high school in Tunceli. It is reported that ten students wounded in the acid-caused explosion at chemistry lab of a private high school in Tunceli. According to the reports the tenth-grade students at Private Özel Munzur science high school were doing an experiment at the chemistry laboratory when an explosion occurred. It was due to acid use. In the explosion ten students were wounded. They were taken to Tunceli Public Hospital through ambulances. **"seven of wounded students were discharged** Tunceli local education director Ali Eyyüpkoca reported that the tenth-grade students at Private Özel Munzur science high school were doing an experiment at the chemistry laboratory when an explosion occurred.*

Source:http://www.trthaber.com/haber/turkiye/okul-laboratuvarinda-talihsiz-kaza-217446.html

Experiment at the School Made a Student Blind: My Tears Hurt Me

21 December 2014

*As a result of the accident during the experiment at a school in İstanbul eyes of a student aged 11 were burned! As a result of the accident during the experiment at a school in Uskudar district of İstanbul eyes of a student aged 11, **Mert Öztoprak**, were burned. Mert stated "I could not see anything. I always cry and my tears hurt me. I will never forgive my teacher who darkened my future". According the **news by Gökhan Karakaş** in*

Milliyet newspaper, on 3 December the sixth-grade students at Ali Fuat Başgil secondary school in Uskudar district of Istanbul were doing an experiment in the laboratory in science course. Science teacher Mehmet Aslan told the students that he would explain the mixture of zinc and mercury using an iron tube. The teacher added that a metal container would be used since the resulting substance could melt a plastic container. The teacher, Mehmet Aslan, asked 11-year-old Mert Öztoprak to help him. He gave the iron tube to Mert and began to pour the zinc and then the liquid mercury. While the student was mixing them using the iron tube the teacher blowed the iron tube. Then it caught fire.

'I will never forgive him.'

Mert had four operations in a week. When he learned that if he used a glass of which price was five liras this event would not, his sorrow increased. Mert reported "While the teacher were pouring mercury into zinc he blowed the iron tube. Then it was exploded in my hand. I recognized that my eyes burned and I extinguished the fire on my hair. He told us that he was a bit clumsy and that he burned his jacket or apron in the experiments. But he fired my future this time."

Source:http://t24.com.tr/haber/okuldaki-deney-kor-etti-gozyaslarim-bile-bana-aci-veriyor,281120

Explosion During an Experiment at a Private School: Two Wounded

03.12.2014

An explosion occurred during the experiment at the science laboratory of a private school in Üsküdar. Teacher Mehmet Aslan and 11-year-old student Mert Öztoprak were injured in the explosion.

The event occurred yesterday at 17.00. The explosion of which the reasons are not clear wounded both the teacher Mehmet Aslan and the student Mert Öztoprak who were helping his teacher. They were both taken to Haydarpaşa Eğitim ve Araştırma Hospital. The face of the teacher burned and he treated at the hospital. The student was wounded from his face and eyes and he was transferred to Kartal Eğitim ve Araştırma Hospital. His treatment is still going on and it is learned that he will had an operation.

Mert Öztoprak's parents and relatives came hospital whenever they heard the accident. His mother Ayşe Öztoprak said "I just sent my son to the school, not to the war. I will sue those people who responsible for his injuries." She added "My son's eyes burned. One his eyes may not see again. How an experiment is this? Students do not use gloves and glasses at the laboratory. Why was my son so near to the experiment? Not my son but another student may be injured at the laboratory. I will sue those people who responsible for his injuries."

Source:http://www.hurriyet.com.tr/ozel-okulda-deney-sirasinda-patlama-2-yarali-27699269

Explosion at the Laboratory During the Experiment

04.03.2015

During an chemistry experiment at the laboratory of Yalova Vocational and Technical Anatolian High School an explosion occurred. Teacher Mustafa Keskiner was injured in the explosion. Parents called for the steps to be taken in order to avoid accidents and wanted that until these steps are implemented all dangerous experiments at the laboratories should be cancelled.

It is reported that the explosion occurred when sodium was contacted with water. Due to the explosion teacher Mustafa Keskiner was injured from his hands and face. He was taken to the hospital. The students were affected by the smoke.

Source:http://www.hurriyet.com.tr/deney-yapilan-laboratuvarda-patlama-28361081

Explosion at a Basic Education School: 6 Wounded

04.06.2012

Spring festival was organized at a basic education school in Kağıthane district of Istanbul. One of the activities covered in the festival was an experiment work. It is reported that an explosion occurred during the experiment. Six students were injured in the experiment. Teachers working at Zuhal basic education school organized a spring festival near to the end of the semester. One of the activities covered in the festival was an experiment work. It is reported that an explosion occurred during the experiment. Six students were injured in the experiment.

Source:http://www.hurriyet.com.tr/ilkogretim-okulunda-patlama-6-yarali-20689960

Therefore, studies at laboratories have some certain risks. It requires that at laboratories there should be a safe working environment (Yılmaz, 2005). Research strongly suggests that necessary information about chemicals should be given before their use in the experiments (Long 2000; Yılmaz 2004a and İdin, Ş. and Aydoğdu, C. 2016). It is certain that safety is the key consideration in all experiments. Safety-related rules are developed and employed not to limit the practical work, but to provide a safe working environment at laboratories (YÖK, 1997). Laboratory safety include the following topics: taking steps to eliminate all kinds of threats towards equipment, machines and tools, teachers, students and school facilities during experiments and other related activities and adopting a scientific approach towards all potential problems (Canel, 1995**).**

Although having information about experiment equipment and tools and about the use of chemicals, it is also important to take steps to mark and store chemicals. Research emphasizes that protecting from dangerous effects of chemicals and from potential danger is significant not only for human safety but also for laboratory facilities and materials (Richards-Babb, Bishoff, Carver, Fisher, & Robertson-Honecker 2009; Wu, Liu, & Lu 2007; West, *Westerlund*, Nelson, Stephenson, & Nyland 2002; Yılmaz 2005; Yılmaz 2004). Yılmaz, Uludağ and Morgil (2001) concluded that undergraduate students do not have higher levels of information about the toxic effects of some solutions and materials and about the protection in organic chemistry laboratories. Therefore, basic education should be much more cautious in work at laboratories. At the laboratories of basic education schools and high schools not many chemicals should be used. Instead, other familiar materials can be used in these experiments to avoid accidents. It is seen that the major reason for accidents at school laboratories is teachers. Teachers should have and adopt a well-established and proper approach towards accidents and risks at laboratories and have necessary education and training on the subject. In order to achieve it teacher training programs may cover courses on laboratory safety and norms. In addition, textbooks should inform both teachers and students about materials to be used in experiments covered. Yılmaz (2005) analyzed the experiments included in chemistry textbook for the first grade of high schools and reviewed the information given regarding these experiments in terms of laboratory safety, chemicals and other relevant points. It was found that textbooks provide no information concerning laboratory safety and about the safety notes on chemicals. Laboratory use techniques include information about the characteristics of chemicals to be used in experiments, safety rules, how to take steps to avoid accidents at laboratories and how to react when an accident occurs at laboratories. It can be defined as a way to be familiar with the characteristics of chemicals to be used in experiments, safety rules, how to take steps to avoid accidents at laboratories and how to react when an accident occurs at laboratories and the scientific approach towards each of these points (Aydoğdu and Candan, 2012).

Laboratories are one of the most effective environments in the schools where experimental studies are carried out and permanent learning is realized by doing. It is thought that laboratory applications positively contribute to the development of psycho-motor skills and meaningful and permanent structuring of the knowledge learned. Such activities encourage students to make research and solve problems. At the same time, it is known that these activities contribute to the use of manual skills and development of communication skills (Hofstein ve Lunetta, 2004). Experimental accidents are among the top events that reveal the importance of laboratory safety. By identifying the characteristics of different experimental accidents that may occur in the laboratory, the awareness about these accidents will be provided in addition to contributing to the development of taking measures against risks.

Şener (2017) analysed the accidents occurred in science laboratories of schools during the years between 2000 and 2016. The study found the data on such accidents by the education level. Table 1 shows the frequency and percentage of these accidents as follows.

As can be seen in Table 1 In 52 news on accidents a total of 63 accidents was reported. By educational levels it is seen that ***8% of these accidents occurred at university level, 24% of these accidents occurred at high school***, ***27% of these accidents occurred at secondary schools and 41% of these accidents occurred at primary schools.*** The rate of the accidents in laboratories of basic education constitutes ***68%*** of all accidents. These findings suggest that both primary school teachers and secondary school teachers should be trained in relation to laboratory practices.

Table 9. Frequency and Percentage Showing the Occurrence of the Accidents in Schools According to Educational Levels

Educational Levels	*F*	*%*
Elementary School First Level (1-5)	17	27
Elementary School Second Level (6-8)	26	41
Highschool	15	24
University	5	8

Note: In 52 news on accidents a total of 63 accidents was reported.

Table 2 indicates the relationship between the educational programs modified and the laboratory accidents at different educational levels.

Table 10. Statistical Relationship between the Educational Programs Modified and the Laboratory Accidents at Different Educational Levels

Educational Programs	Elementary School First Level	Elementary School Second Level	Highschool	University	Total Accidents
2000 – 2004	2	—	—	—	2
2005 – 2012	7	16	6	3	32
2013 – 2016	8	10	9	2	29
Total Accidents	17	26	15	5	63

Note: In 52 news on accidents a total of 63 accidents was reported.

As Table 2 shows that of 52 accidents there were only two laboratory accidents at primary school between 2000 and 2004. During the same period there was no news on laboratory accidents at high schools and university. During the period between 2005 and 2012 there were seven accidents at primary schools and 16 accidents at secondary schools. The highest number of accidents was during ths period at basic education institutions. In the primary school the accidents were mostly reported to occur due to mercury poisoning. During this period there were six laboratory accidents at high schools and three accidents at universities. Of 52 accidents 32 occurred during this period. Between 2013 and 2016 there were eight laboratory accidents at primary schools, ten accidents at secondary schools, nine accidents at high schools and two accidents at universities. From 2005 to 2012 there were 23 laboratory accidents at basic education institutions and six accidents at high schools. During the years between 2012 and 2016 there were 18 laboratory accidents at basic educaton institutions and nine accidents at high schools. It is seen that the laboratory accidents decreased at basic education institutions during the period analysed while these accidents increased at high schools.

Tekbıyık et. al. (2017) analysed the laboratory accidents and experiment-related accidents in Turkey between 2001 and 2017. They found out 34 accidents occurred in laboratories. It was also found that the highest number of experiment-related accidents occurred at the course of eightht grade science and technology courses. The highest number of accidents occurred in 2012.

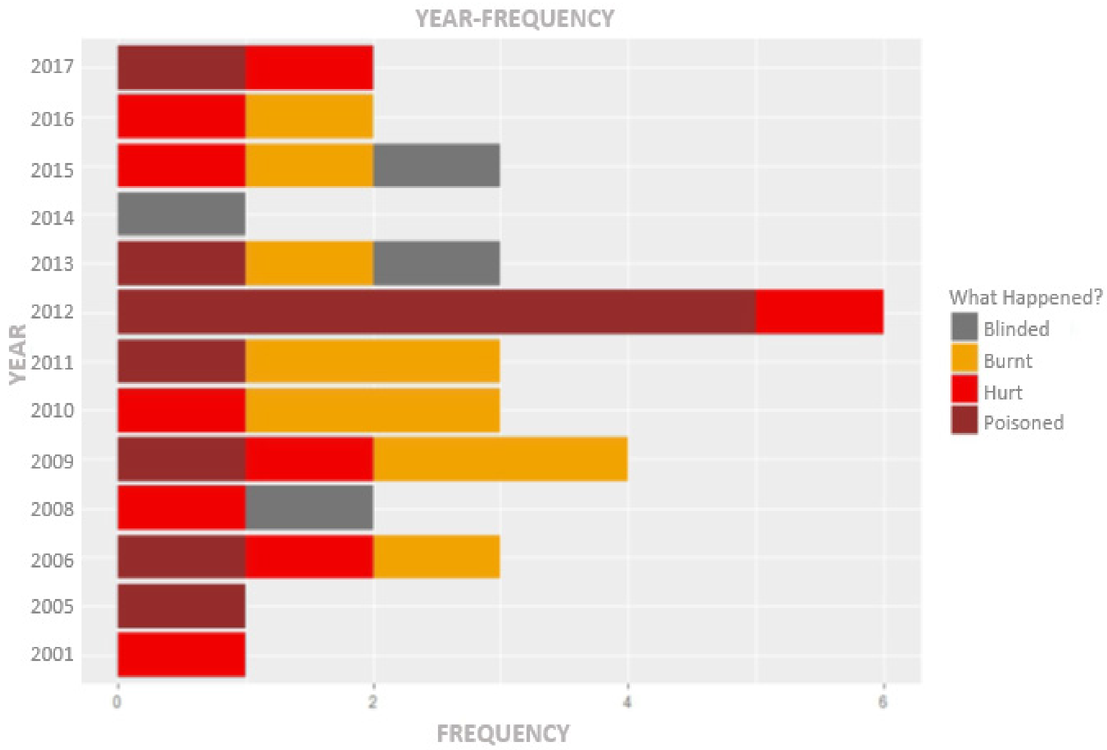

Figure 1. Changes in Health Problems Caused by Accidents Over The Years (Tekbıyık et. al., 2017)

As can be seen in Figure 1 the accidents that resulted in poisoning have occurred the most frequently and burning and injury cases were also experienced intensively. In addition, the accidents that resulted in loss of vision also occured. The most frequent reason for accidents was found to be test tube explosion. These accidents caused serious health problems such as burning, injury and vision loss. In addition, there were also cases of injury as a result of contact with mercury poisoning and burning of fumes in the stove. These cases were also frequent.

In 2009 the General Directorate of Pharmaceuticals and Pharmacy of the ministry of health reported "the introductions of mercury thermometers into the market and their use were hazardous to health and safety for measuring body temperature" and their sales were banned (URL-1). This announcement was also transmitted to the ministry of national education and the higher education institution stating ''in case of inhalation of mercury vapor, it is not possible to expel from the body; mercury vapor can easily pass through the cell membrane to reach the brain and mercury vapor may accumulate in tissues over time and lead to irreversible neurological findings."

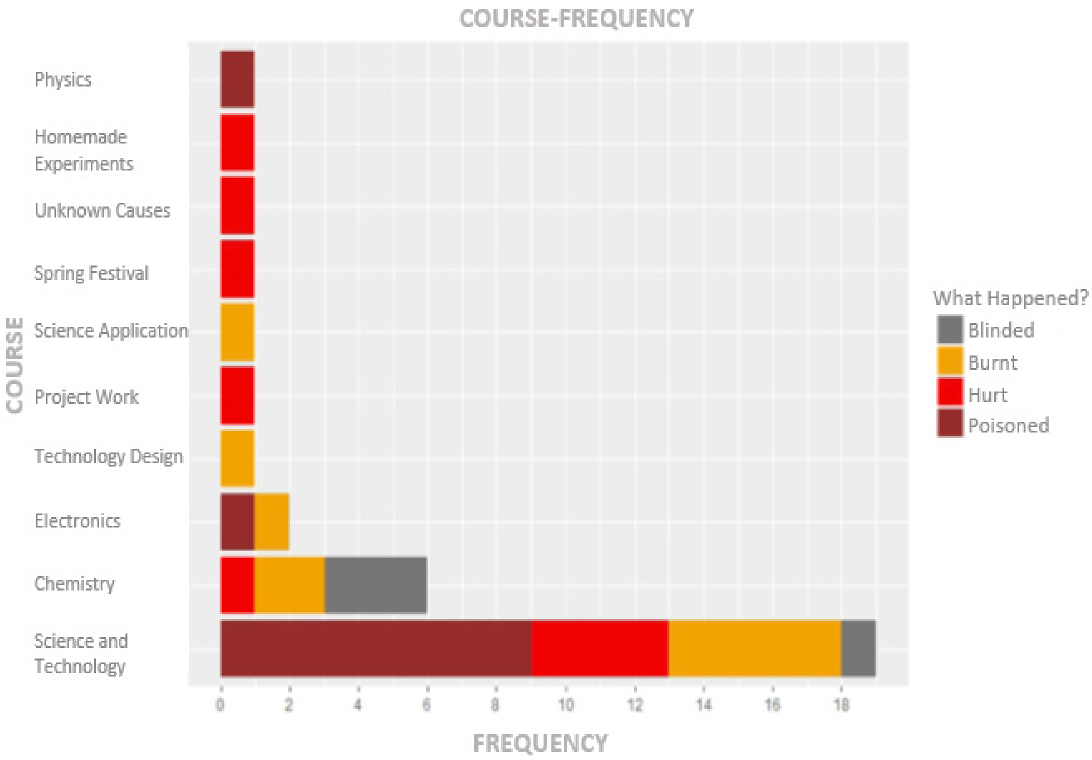

Figure 2. Changes in Health Problems Caused by Accidents by the Courses (Tekbıyık et. al., 2017)

Therefore, it was demanded "mercury thermometers should not be employed on patients, by health-care workers and by students and teachers in school laboratories in terms of health and safety concerns." (URL-1). In addition, the ministry of health declared the necessary steps to be taken in order to avoid mercury poisoning (Ministry of Health, 2013). However, the cases of mercury poisoning are still experienced suggesting that such warnings are not taken into consideration.

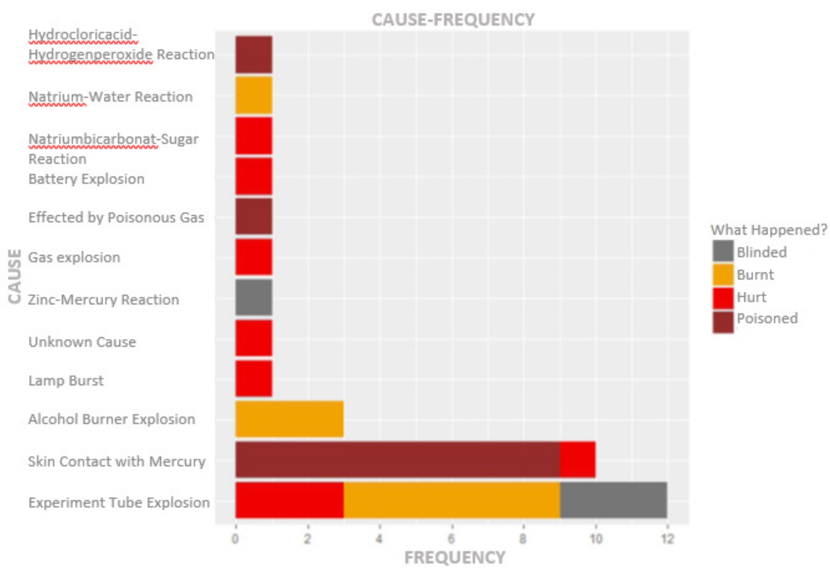

Figure 3. Changes in Health Problems Caused by Accidents Over the Causes of the Accidents (Tekbıyık et. al., 2017)

Laboratory safety

Laboratory safety refers to the process in which necessary steps are taken to avoid hazardous events at school laboratories, to arrange the space in accordance with safety concerns and to solve problems scientifically (Canel, 1995; Bayraktar, Erten & Aydoğdu, 2006; Aydoğdu & Şener, 2016; Aydoğdu, 2017).

In order to work at laboratories in a safe manner students should be informed by teachers about the potential dangers and the steps to be taken in order to avoid accidents and safety guidelines. For this purpose, teachers first should be informed about this points and if necessary, they should be informed about these guidelines through in-training activities and seminars (Hamurcu, 1998).

There are some rules that students in the laboratory should know and adhere to. Hasenekoğlu (2003) listed these rules as follows:

- Safe working in the laboratory should be given importance and it should be a habit of students.
- Individuals working in the laboratory should also pay attention to the safety of their peers.
- They should be knowledgeable about and careful against the dangers that may occur in laboratories.
- They should be informed about what to do when an emergency is encountered.
- These persons should report the dangerous situations and accidents in the laboratory to those concerned.

People should be aware of the dangers that may occur in the laboratory as well as necessary steps to be taken. In addition, they should do what to do in undesirable conditions. All procedures should be completely and correctly implemented (Bulduk, 2014). Therefore, the following points should be taken into account:

- The characteristics of the chemicals to be used should be well known. People should be careful while working at laboratories.
- The operating instructions of the tools and equipment must be read carefully and followed.
- People working at laboratories must have sufficient knowledge and skills against hazards arising from tools and equipment.
- First aid to be applied at the time of the accident should be done quickly and in accordance with the method (MONE, 2008).

Ergin, Pekmez and Erdal (2005) listed the materials required for laboratory safety in the school laboratories as follows:

- Emergency kit
- Fire extinguisher tubes
- Sand bucket
- Fire blanket
- Suitable places for eye wash
- A shower to be used in case of danger
- Safety glasses
- Smock
- Heat resistant gloves
- Protective gloves from chemicals

Label Reading and Safety Data Sheets

In order to be able to work safely in the laboratory, it is necessary to know ”label reading”. It is necessary to know the properties of the chemicals to be used and the risk pictograms on the chemical flask to prevent accidents. A regulation on the Classification Labelling and Packaging (CLP regulation) was published on 30 December 2008 concerning the classification, labelling and handling of chemicals and mixes, and it came into force on 20 January 2009. The CLP regulation aims to provide a high level of protection for human health and the environment against the risks that may arise from the harmful properties of chemicals and to ensure the free movement of substances, mixtures and articles.. Aydoğdu ve Şener (2016) produced a comparison of old hazard symbols and new risk pictograms provided by the CLP regulations as given in Figure 4.

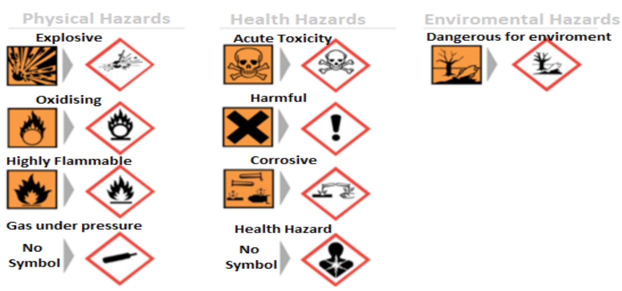

Figure 4. A Comparison of Old Hazard Symbols and New Risk Pictograms

To have more information on the chemicals used, it is possible to use the chemical safety data sheet. These forms contain the following information:

- Information about the producer
- Danger information about the product
- Content of the product
- Health and environmental measures to be taken if the product is exposed
- Measures to be taken during transport, storage and use of the product
- Classification of the product
- Things to do in case of fire and accidents
- Waste disposal information
- Toxicology and ecotoxicology information about the product

Readers of safety data sheets have complete information about the product they use. They will also know how to handle, how to store, how to handle, and how to behave if they are exposed. (Aydoğdu & Şener, 2016).

Storage of chemical substances

In the laboratory and the places where the chemicals are stored, the most frequent accidents usually occur in the form of fire and explosion. In order to prevent these accidents that may occur the characteristics of chemicals must be known, and storage should be done accordingly.

Figure 5 shows how chemicals should be stored based on the risk pictograms. In storing the chemicals th following points should be taken into consideration to avoid any accidents;

- ✓ Chemicals must never be stored in alphabetical order.
- ✓ Instead, chemicals should be stured based on chemical and physical characteristics.
- ✓ Containers in which substances are placed for proper storage must be properly labeled.
- ✓ Some chemicals require storage in a cold environment, some in a dry environment, some in a humid environment, and some in a light-free environment.

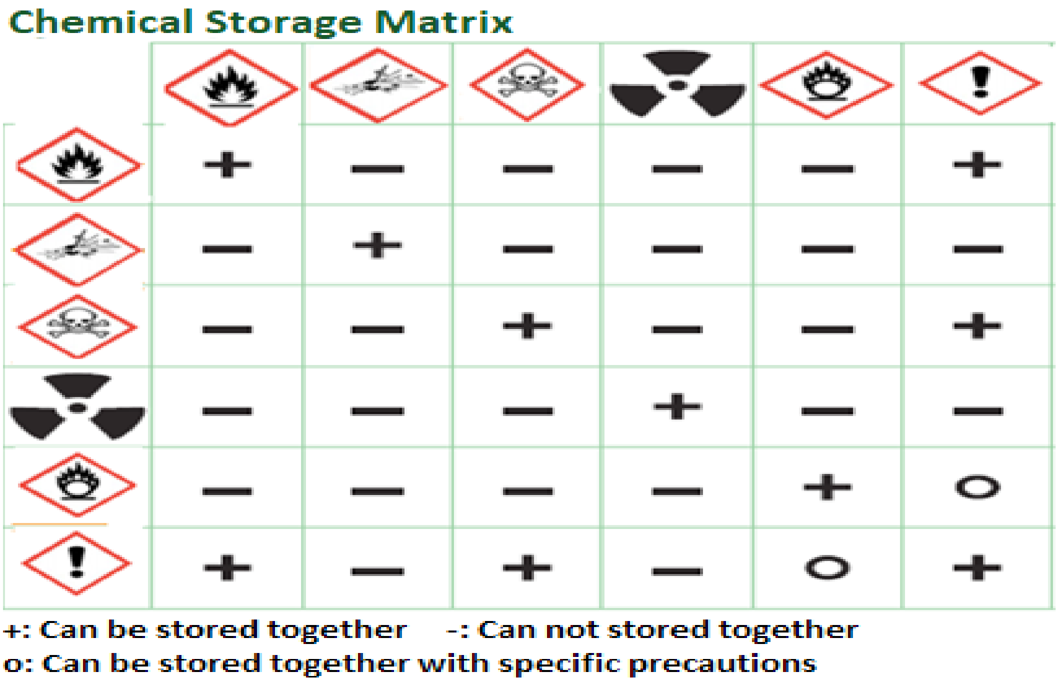

Figure 5. Storing Matrix for Chemicals

- Warehouses must be equipped with systems such as ventilation, fire fighting, alarm and insulation against heat.
- Shelves where chemical substances are placed should not be made of wood. Shelves made of materials such as iron and aluminum can cause fire by giving exothermic reactions as a result of chemical substances. It is appropriate to place more inert substances on such shelves.
- Rack heights should not exceed 2 m for easy use, should be wall mounted, and the front of the shelves should be surrounded by protection strips.
- Chemicals should be placed on the shelves according to their class codes.
- Flammable and explosive substances should be stored in fire and explosion-proof warehouses.
- An inventory system should be prepared to record all chemicals.
- Gas and smoke detector and fire warning system must be built in warehouses.
- Bottles and packages containing all chemicals must be labeled.
- Light-degradable substances should be stored in such a way that they are kept away from light and sun.
- Explosive and flammable materials should be stored away from other explosive and flammable materials.

- Materials such as white phosphorus and sodium, potassium should be stored in liquid paraffin in appropriate bottles.
- Hazardous chemicals should be kept away from sources of fire in a well-ventilated, moisture-free environment and be away from matches and lighters, etc.
- Chemicals that should never come into contact with each other should never be placed side by side on the same shelf.

References

Akbaba, T. (2004). “Cumhuriyet Döneminde Program Geli_tirme Çalı_maları”, *Bilim ve Aklın Aydınlıında Eğitim Dergisi, cilt. 5*, sayı. 54–55.

Akkuş, H. & Kadayıfçı, H. (2007). “Laboratuvar kullanımı” konulu hizmet-içi eğitim kursu ile ilgili bir değerlendirme. *Gazi Eğitim Fakültesi Dergisi, 27* (1), 179-193.

Akyüz. Y. (2008). Türk Eğitim Tarihi, Ankara: PegemA Yayıncılık, 12. Baskı.

Akyüz, Y. (1994). Türk Eğitim Tarihi (Başlangıçtan 1993’e) İstanbul Kültür Koleji Yayınları *Eğitimde Arayışlar Dizisi: 4*, s. 290.

Arslan, M. (2000). “Cumhuriyet Dönemi _lköğretim Programları ve Belli Başlı Özellikleri”, *Milli Eğitim Dergisi, sayı. 146.*

Aslan, E. (2011). Türkiye Cumhuriyeti\’nin İlkokullarda İzlediği İlk Öğretim Programı: “1924 İlk Mektepler Müfredat Programı”. *İlköğretim Online, 10*(2). 717–734.

Ayas, A. (1995) Fen Bilimlerinde Program Geliştirme ve Uygulama Teknikleri Üzerine Bir Çalışma: İki Çağdaş Yaklaşımın Değerlendirilmesi, *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 11*, 149-155.

Arslan, M. (2012). “Cumhuriyet Dönemi İlköğretim Programları ve Belli Başlı Özellikleri”, *Milli Eğitim Dergisi, s. 144*, s. 45-51.

Ayas, A., Çepni, S., Akdeniz, A.R. (1993). Development of the Turkish Secondary Science Curriculum, *Science Education, 77*, (4), 433-440.

Ayaş, A., Çepni, S. & Akdeniz, A. R. (1994). Fen bilimleri eğitiminde laboratuvarın yeri ve önemi; tarihsel bir bakış. *Çağdaş Eğitim, 204*, 21-25.

Ayas, A. (1995). Fen Bilimlerinde Program Geliştirme ve Uygulama Teknikleri Üzerine Bir Çalışma: İki Çağdaş Yaklaşımın Değerlendirilmesi, *HacettepeÜniversitesi Eğitim Fakültesi Dergisi, 11*, 149-155.

Ayas, A., Özmen, H., Demircioğlu, G., Sağlam, M. (1999). Türkiye'de ve Dünyada Yapılan Program Geliştirme Çalışmaları: Kimya Açısından Bir Derleme, *D.E.Ü. Buca Eğitim Fakültesi Dergisi Özel Sayı, 11*, 211-219.

Aydoğdu, C. (1999). Kimya Laboratuvar Uygulamalarında Karşılaşılan Güçlüklerin Saptanması. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi. 15*. (30-35).

Aydoğdu, C. & Candan, S.(2012). Fen ve Teknoloji Dersine ait Bazı Etkinliklerin Laboratuvar Kullanım Tekniği Açısından İncelenmesi, *Journal of Contemporary Education Academic,1*(4),32-43.

Aydoğdu, C. & Yardımcı, E.(2013). İlköğretim Fen Laboratuvarlarında Meydana Gelen Kazalar Ve Öğretmenlerin Geliştirebilecekleri Davranış Tarzları, *H. Ü. Eğitim Fakültesi Dergisi [H. U. Journal of Education] 44*, 52-60

Aydoğdu, C.(2015). Science and Technology Teachers' Views About The Causes of laboratory Accidents, *International Journal of Progressive Education, Volume 11 Number 3*, 106-117.

Aydoğdu, C.(2017). The Effect Of Chemıstry Laboratory Actıvıtıes On Students' Chemıstry Perceptıon And Laboratory Anxıety Levels, *International Journal of Progressive Education, Volume 13*, Number 2, 85-94.

Aydoğdu, M. & Kesercioğlu, T. (2005). *İlköğretimde Fen ve Teknoloji Öğretimi*. Ankara: Anı Yayıncılık.

Aydoğdu, C. & Pekbay, C. (2016). Sınıf öğretmen adaylarının laboratuvarlarda yaşanan kazaların nedenlerine yönelik görüşleri. *Eğitim, Bilim ve Teknoloji Araştırmaları Dergisi, 1*(2), 103-112.

Aydoğdu, C. & Şener, F. (2016). Fen Eğitiminde Laboratuvar Kullanım Tekniğinin ve Güvenliğin Önemi ve CLP Tüzüğünün Getirileri Üzerine Bir Araştırma. *ESTÜDAM, 1*(1).

Aydoğdu, C.,(2017). "The Use Of Laboratorıes In Scıence Teachıng" Editors: Dr. Mack Shelley & Dr. Mustafa Pehlivan. *Education Research Highlights in Mathematics, Science and Technology 2017* Published by ISRES Publishing, International Society for Research in Education and Science (ISRES). ISBN: 978-605-67951-1-4.

Alpaut, O. (1993). Fen Eğitiminin Verimli Ve İşlevsel Hale Getirilmesi. Ortaöğretim kurumlarında fen öğretimi ve sorunları Sempozyumu, TED, Ankara.

Başar, E. (2004). *Milli Eğitim Bakanlarının Eğitim Faaliyetleri* (1920-1960), İstanbul: Milli Eğitim Basımevi

Binbaşıoğlu, C. (1995) *Türkiye'de Eğitim Bilimleri Tarihi*, MEB Yayınları, İstanbul.

Böyük, U., Demir, S. & Erol, M. (2010). Fen ve teknoloji dersi öğretmenlerinin laboratuvar çalışmalarına yönelik yeterlik görüşlerinin farklı değişkenlere göre incelenmesi. *TÜBAV Bilim Dergisi, 3* (4), 342-349.

Browne, CA. (1941). The first high-school chemistry laboratory? *Journal of Chemical Education, 18*(8), 395. doi: 10.1021/ed018p395

Bulduk, Ö. (2014). *Fen ve teknoloji dersi 7. sınıf ders kitabı ve öğretmen klavuz kitabının laboratuvar kullanım tekniği açısından incelenmesi* (Yayımlanmamış yüksek lisans tezi). Hacettepe Üniversitesi, Ankara.

Canel, M. (1995). *Laboratuvar güvenliği, (no:26)*. Ankara: Ankara Üniversitesi Fen Fakültesi, Döner Sermaye İşletmesi Yayınları.

Cicioğlu, H. (1985) *Türkiye Cumhuriyetinde İlk ve Orta Öğretim (Tarihi Gelişimi)*, Ankara: Ankara Üniversitesi Eğitim Bilimleri Fakültesi Yayınları No 140.

Collette, E.L. & Chiapetta, A. (1989). *Teaching Science In Middle And Secondary Schools*., Berril PublishingCompany, Toronto.

Çallıca, H., Erol, M., Sezgin, G. & Kavcar, N. (2001). *İlköğretim Kurumlarında Laboratuvar Uygulamalarına İlişkin Bir Çalışma*. IV. Fen bilimleri eğitimi Sempozyumu, Milli Eğitim Basımevi, Ankara

Çepni, S., Kaya, A. & Küçük, M. (2005). Fizik öğretmenlerinin laboratuvarlara yönelik hizmet içi ihtiyaçlarının belirlenmesi. *Türk Eğitim Bilimleri Dergisi, 2*(3), 181-196.

Çilenti, K. (1985).*Fen Eğitimi Teknolojisi*. Kadıoğlu Matbaası, Ankara.

Demir, E. (2016). *Fen laboratuvarlarının fiziki şartlarının ve fen bilimleri öğretmenlerinin laboratuvar güvenliği konusundaki bilgi düzeylerinin araştırılması* (Yüksek lisans tezi). Gazi Üniversitesi, Ankara.

Demir, S. (1998). *Cumhuriyet Döneminde Program Geliştirme Açısından Hayat Bilgisi Programlarının incelenmesi*, Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, Yayınlanmamış Yüksek Lisans Tezi.

Demirbaş, M., Soylu, H. (2000). *Türkiye'de Etkili Fen Öğretimi İçin 1960-1980 Yılları Arasında Geliştirilen Programlar*, IV. Fen Bilimleri Eğitimi Sempozyumu, Hacettepe Üniversitesi, Ankara.

Demirel, Ö. (1992). "Türkiye'de Program Geliştirme Uygulamaları", *Hacettepe Üniversitesi, Eğitim Fakültesi Dergisi, sayı. 7*, ss. 27-43.

Demirel, Ö. (1998). *Eğitimde Program Geliştirme*, İstanbul: Pegem A Yayıncılık.

Dewey, J. (1939). *Türkiye Maarifi hakkında rapor (Report about Turkish education)*, İstanbul: Devlet Basımevi.

Dindar,H. & Taneri A.,(2011). MEB'in 1968, 1992, 2000 Ve 2004 Yıllarında Geliştirdiği Fen Programlarının Amaç, Kavram Ve Etkinlik Yönünden Karşılaştırılması, *Kastamonu Eğitim Dergisi, Cilt:19 No:2*, 363-378

Ekici,G. (1996). *Biyoloji Öğretmenlerinin Öğretiminde Kullandıkları Yöntemler Ve Karşılaştıkları Sorunlar.* Yayınlanmamış yüksek lisans tezi, Ankara Üniversitesi, Ankara.

Elliott, MJ, Stewart, KK, & Lagowski, JJ. (2008). The Role of the Laboratory in Chemistry Instruction. *Journal of Chemical Education, 85*(1), 145. doi: 10.1021/ed085p145

Ergin, Ö., Pekmez, E.Ş. & Erdal, S.Ö. (2005). *Kuramdan uygulamaya deney yoluyla fen öğretimi*. İzmir: Dinazor Kitabevi.

Ersoy, Y. (2013). Fen ve Teknoloji Öğretim Programındaki Yenilikler-I: Değişikliğin Gerekçesi ve Bileşenlerinin Çerçevesi. 1-20. [Online]: http://www.f2e2-ogretmen.com/ dağarcığımız/f2e2-32.pdf adresinden 5 Ağustos 2013 tarihinde indirilmiştir.

Erten,S. (1991). *Biyoloji Laboratuvarlarının Önemi ve Laboratuvarda Karşılaşılan Güçlükler*. Yayınlanmamış yüksek lisans tezi, Gazi Üniversitesi, Ankara.

Fay, PJ. (1931). The history of chemistry teaching in American high schools. *Journal of Chemical Education, 8*(8), 1533. doi: 10.1021/ed008p1533

Fife, WK. (1975). Instruction in the organic chemistry laboratory: Past, present, and future. *Journal of Chemical Education, 52*(2), 119. doi: 10.1021/ed052p119

Gömleksiz, M.N. , & Bulut, İ. (2006). Yeni fen ve teknoloji dersi öğretim programına ilişkin öğret¬men görüşleri. *Fırat Üniversitesi Sosyal Bilimler Dergisi, 16*(2), 173-192.

Gömleksiz, M.N. , & Bulut, İ. (2007). Yeni fen ve teknoloji dersi öğretim programının uygulama¬daki etkililiğinin değerlendirilmesi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 32*, 76-88.

Gözütok, D. (2003). "Türkiye'de Program Geliştirme Çalışmaları", *Milli Eğitim Dergisi*, s. 160, ss. 44-64.

Gürdal, A. (1991). *Fen Öğretiminde Laboratuar Etkinliğinin. Başarıya Etkisi. Özel kültür okulları eğitim araştırma geliştirme merkezi eğitimde yeni arayışlar* I. Sempozyumu. Eğitimde nitelik geliştirme. İstanbul.

Güven, İ., Öztuna, A. & Gürdal A. (2002). *İlköğretim Bölümü Öğrencilerinin Fen Bilgisi Laboratuvar Uygulamaları Hakkındaki Görüşleri*. 2000'li yıllarda I. öğrenme ve öğretme Sempozyumu. İstanbul

Hançer, A. H., Şensoy, Ö., & Yıldırım, H. İ. (2003). İlköğretimde Çağdaş Fen Bilgisi Öğretiminin Önemi Ve Nasıl Olması Gerektiği Üzerine Bir Değerlendirme. *Pamukkale Üniversitesi Eğitim Fakültesi Dergisi, 13*(13), 80-88.

Hasenekoğu, İ. (2003). *Laboratuvar güvenliği (2-3)*, Erzurum: Kazım Karabekir Eğitim Fakültesi Yayınları. Merck Laboratuvar El Kitabı, (2011).

Hofstein, A. & Lunetta, V. N. (2003). The laboratory in science education: foundations forthe twenty-first century. *Science Education, 88*, 28-54.

Hofstein, A. & Lunetta, V.N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education, 88*, 28-54. Erişim adresi:

Hofstein, A. & Naaman, R. M. (2007). The laboratory in science education: the state of the art. *Chemistry Education Research and Practice,8* (2), 105-107.

Hofstein, A., Nahum, T. L. & Shore, R. (2001). Assessment of the learnıng envıronment of ınquıry-type laboratorıes ın hıgh school chemıstry. *Learning Environments Research, 4*, 193–207.

İdin, Ş. & Aydoğdu, C. (2016). 'Asit ve Bazın Tahribatları' Etkinliğinin Laboratuvar Kullanım Teknikleri Açısından İncelenmesi Üzerine Bir Uygulama Çalışması. *Amasya Üniversitesi Eğitim Fakültesi Dergisi, 5*(2), 606-635.

İlköğretim okulunda patlama: 6 yaralı 04.06.2012 - 15:15 | Son Güncelleme: 04.06.2012http://www.hurriyet.com.tr/ilkogretim-okulunda-patlama-6-yarali-20689960

İlkokul Müfredat Programı (1924) Maarif Vekâleti Yayını, Milli Eğitim Basımevi: Ankara.

İlkokul Müfredat Programı (1926) Milli Eğitim Bakanlığı Yayını, Milli Eğitim Basımevi: İstanbul.

İlkokul Müfredat Programı (1936) Maarif Vekâleti Yayını, Devlet Basımevi: İstanbul.

İlkokul Programı (1948). Milli Eğitim Bakanlığı Yayını, Milli Eğitim Basımevi: İstanbul.

İlkokul Programı (1968). Milli Eğitim Bakanlığı Yayını, Milli Eğitim Basımevi: İstanbul.

Kaya, H., & Böyük, U. (2011). Fen bilimleri öğretmenlerinin laboratuvar çalışmalarına yönelik yeterlikleri. *Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 27*(1), 126-134.

Kılıç, D., Keleş, Ö. & Uzun, N. (2015). Fen bilimleri öğretmenlerinin laboratuvar kullanımına yönelik özyeterlik inançları: laboratuvar uygulamaları programının etkisi. *EÜ Eğitim Fakültesi Dergisi,17*(1), 218-236.

Kıncal, R. (1993) *"Türkiye'de İlkokul Programlarının Hazırlanmasında Demografik, Ekonomik, Siyasal ve Kültürel Faktörlerin Yeri"* Eğitim Bilimleri Birinci Ulusal Kongresi, Ankara Üniversitesi Eğitim Bilimleri Fakültesi Yayınları, ss. 299-307.

Kızıldağ, S. (2009). *Akademik başarının yordayıcısı olarak yalnızlık, boyun eğici davranışlar ve sosyal destek*. Hacettepe Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, Ankara

Kirschner, P. A. & Meester, M. A. M. (1988).The laboratory in higher science education: Problems, premises and objectives. *Higher Education, 17*, 81-98.

Kural, E.(2011). Laboratuvarda İş sağlığı ve Güvenliği, Subcon turkey- Yan Sanayi ve Tedarikçi Gazetesi, Haziran sayısı.

Küçükoğlu, A. & Bay E. (2007). Eğitimin felsefi temelleri. D. Ekiz ve H. Durukan (Ed.), *Eğitim Bilimine Giriş*. Ankara: Lisans Yayıncılık.

Lawson, A. E. (1995). *Science Teaching And The Development Of Thinking*. Wadsworth Pres., California.

MEB İlköğretim Fen Ve Teknoloji Dersi (4-5. Sınıflar) Öğretim Programı, Devlet Kitap¬ları Müdürlüğü Basım Evi, Ankara

MEB (1968). *İlkokul Programı*, Milli Eğitim Basım Evi, İstanbul.

MEB., Tebliğler Dergisi, Cilt:53, Sayı:2365, Ankara, Ağustos-1992.

MEB., Tebliğler Dergisi, Cilt:63, Sayı2518, Ankara, Kasım-2000.

MEB. (2012). 12 Yıl Zorunlu Eğitim Sorular-Cevaplar, Ankara. [Online]: http://www.meb.gov.tr/ duyurular/duyurular2012/12Yil_Soru_Cevaplar.pdf adresinden 25 Eylül 2012 tarihinde indirilmiştir.

MEB. (2013). İlköğretim Kurumları (İlkokullar ve Ortaokullar) Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı, Ankara.

MEB-TTKB. (2013b). İlköğretim Kurumları (İlkokullar ve Ortaokullar) Fen Bilimleri Dersi (3.-8. Sınıflar) Öğretim Programı Konulu, 7 Sayılı Kararı, 2013.

MEB. (2018). İlköğretim Kurumları (İlkokullar ve Ortaokullar) Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. Sınıflar) Öğretim Programı, Ankara.

Nakiboğlu, C.; Sar_kaya, _. (1999). Orta ö retim Kurularında Kimya Derslerinde Görevli Öğretmenlerin LaboratuvardanYararlanma Durumlarının Değerlendirilmesi. *D.E.Ü. Buca E itim Fakültesi Dergisi Özel Say. 11.* (395-405).

Nakiboğlu, C.; İşbilir, A. (2001). *Orta öğretim Kurumlarında Biyoloji Derslerinde Görevli Öğretmenlerin LaboratuvardanYararlanma Durumlarının Değerlendirilmesi*. Maltepe Üniversitesi Fen Bilimleri Eğitimi Sempozyumu. İstanbul.

Newell, LC. (1925). The founders of chemistry in America. *Journal of Chemical Education, 2*(1), 48. doi: 10.1021/ed002p48

Odubunni, O & Balagun, T. A. (1991). The Effect Of Laboratory And Lecture Teaching Methods On Cognitive Achivement in Integrated Science. *Journal Of Researrch In Science Teaching, 28*, 213-224.

Okul laboratuvarında talihsiz kaza, 21 Kasım 2015 Cumartesi http://www.trthaber.com/haber/turkiye/okul-laboratuvarinda-talihsiz-kaza-217446.html Okuldaki deney kör etti: Gözyaşlarım bile bana acı veriyor! 21 Aralık 2014 http://t24.com.tr/haber/okuldaki-deney-kor-etti-gozyaslarim-bile-bana-aci-veriyor,281120

Özel okulda deney sırasında patlama: 2 yaralı 04.12.2014 - Son Güncelleme: 03.12.2014 http://www.hurriyet.com.tr/ozel-okulda-deney-sirasinda-patlama-2-yarali-27699269

Özinönü, A. K. Türk Orta Ögretim Fen Müfredatında Deiişme ve Egilimler TÜBİTAK V. Bilim Kongresi BAYG Tebligleri s: 41.

Raju, T. J. M. S., & Suryanarayana, N. V. S. (2011). The Availability And Use of Science Laboratories At Secondary Education Level. *i-Manager's Journal on School Educational Technology, 7*(2), 46.

Sağlık Bakanlığı HSGM (2013). Cıva zehirlenmesi ve alınması gereken önlemler, http://cevresagligi.thsk.saglik.gov.tr/bilgi-dokumanlar/halk-sagligina-yonelik/994-civa-zehirlenmesi-ve-al%C4%B1nmas%C4%B1-gereken-%C3%B6nlemler.html adresinden 29 Ağustos 2018 tarihinde alınmıştır.

Stephenson, A. L., West, S. S., Westerlund, J. F., & Nelson, N. C. (2003). An analysis of incident/accident reports from the Texas Secondary School Science Safety Survey, 2001. *School Science and Mathematics, 103*(6), 293-303.

Sheppard, K, & Horowitz, G. (2006). From Justus von Liebig to Charles W. Eliot: The Establishment of Laboratory Work in U.S. High Schools and Colleges. *Journal of Chemical Education, 83*(4), 566. doi: 10.1021/ed083p566

Sheppard, K, & Robbins, DM. (2005). Chemistry, The Central Science? The History of the High School Science Sequence. *Journal of Chemical Education, 82*(4), 561. doi: 10.1021/ed082p56

Soylu, H. TüBİTAK V. Bilim Kongresi BAYG Tebligleri s: 157.

Sönmez, V. (1996), *Program Geliştirmede Öğretmen El Kitabı*, Yargı Yayınları-1: Ankara.

Şahin, M.(2009). Cumhuriyetin Kuruluşundan Günümüze Türkiye'de Hayat Bilgisi Dersi Programlarının Gelişimi. *The Journal of International Social Research Volume 2 / 8*,402-410.

Şener, F.(2017). *Okullarda Yaşanan Yazılı Ve Görsel Basına Yansıyan Fen Laboratuvar Kazaları*, Yayımlanmamış Yüksek Lisans Tezi, Hacettepe Üniversitesi, ANKARA. Takvim.com.tr /09.12.2011

Tekbıyık, A. & Tepe, M.(2017). Türkiye'de 2001-2017 Yılları Arasında Yaşanan Laboratuvar Ve Deney Kazalarının Değerlendirilmesi. *The International Journal of Innovative Approaches in Education* Volume 1 Issue 1.

Tazebay A., Çelenk S., Tertemiz N., Kalaycı N. (2000) İlköğretim Programları ve Gelişmeler, Nobel Yayın Dağıtım, Ankara.

Turgut, M. F., Baker, D., Cunnigham, R. & Piburn, M. (1997). İlköğretim Fen Öğretimi. YÖK- Dünya Bankası Yayınları, Ankara.

Uluçınar, Ş., Cansaran, A., & Karaca, A. (2004). Fen bilimleri laboratuvar uygulamalarinin değerlendirilmesi. Türk Eğitim Bilimleri Dergisi,2(4), 465-475.

URL-1 https://www.sabah.com.tr/yasam/2009/10/28/civali_termometrelere_dikkat adresinden 29 Ağustos 2018 tarihinde alınmıştır.

Ünal, S. (2003). *Lise 1 ve 3 Öğrencilerinin Kimyasal Bağlar Konusundaki Kavramları Anlama Seviyelerinin Karşılaştırılması*, Yayımlanmamış Yüksek LisansTezi, Karadeniz Teknik Üniversitesi, Trabzon.

Ünal, S., Çoştu, B. & Karataş, F.,Ö., (2004). Türkiye'de Fen Bilimleri Eğitimi Alanındaki Program Geliştirme Çalışmalarına Genel Bir Bakış, *Gazi Eğitim Fakültesi Dergisi, Cilt 24*, Sayı2 183-202

Varış, F. (1988). *Eğitimde Program Geliştirme*, Ankara Üniversitesi Eğitim Bilimleri Fakültesi Yayını No: 157, Ankara.

Varış, F. (1996). *Eğitimde Program Geliştirme*, Ankara: Alkım Yayınları.

Wilson H. E. & Başgöz İ. (1973), *Türkiye Cumhuriyetinde Eğitim ve Atatürk*, Dost yayınları, Ankara.

Yılmaz A., İnci M. (1999)., "Kimya Öğretmenliği Öğrencilerinin Laboratuvar Uygulamalarında Kullandıkları Laboratuvarların Şimdiki Durumu ve Güvenli Çalışmaya İlişkin Öğrenci Görüşleri", *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, vol.15*, pp.104-109

Yılmaz, A. (2004). Lise-3 kimya ders kitabında mevcut deneylerde kullanılan kimyasalların insan sağlığı ve güvenliği açısından tehlikeli özelliklerine yönelik öğrencilerin bilgi düzeyleri ve öneriler. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 27*, 251-259.

Yılmaz, A. (2004a). *Laboratuvarda Güvenli Çalışma*. Ankara: Hacettepe Üniversitesi Yayınları.

YÖK/ Dünya Bankası,(1997). Fen öğretiminde güvenlik, Ankara.

Yolcu, O. (2014). *Cumhuriyetten (1923) Günümüze (2013) İlköğretim Birinci Kademe Hayat Bilgisi ve Fen ve Teknoloji Öğretim Programlarının "Çevre Eğitimi" Açısından İncelenmesi*, Adnan Menderes Üniversitesi Sosyal Bilimler Enstitüsü Eğitim Bilimleri Anabilim Dalı Yüksek Lisans Tezi.

Redefining Multicultural Science Education and Adopting Indigenous Science as "Classroom Science"

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Introduction

We have been fortunate to be involved in a project that aims to train teachers on the 'proper' use of inquiry approach in teaching science. In one of our region-wide trainings, one of the activities required teachers to revise the ready-made daily lesson log (as provided by the Department of Education) making it an inquiry-based one. During the presentation and critiquing of each other's work, we noticed that teachers from rural areas would comment that a lesson presented by a teacher from a more urbanized area is not applicable to their situation for the reason that their students could either not relate/connect with the examples and illustrations used or that they do not have the instructional resources needed to deliver the lesson as suggested. We realized, based on the teachers' arguments and discussions that the "one-size-fits-all" notion is false.

In one of our research projects, we had the chance to visit three "minority schools" in Occidental Mindoro, Philippines and be able to learn how they are operating as learning institutions to the *Iraya Mangyans* (the natives of Mindoro). In terms of curriculum, in science and other areas, they are following the national curriculum with English as the medium of instruction for Science. What situates them from the "regular schools" is the mere presence of an indigenous group of learners. Although, we observed that their pacing in learning Science is relatively slow and teachers find it impossible to cover all prescribed topics in the curriculum. From our interviews, the teachers would wish for a curriculum specifically designed for their culturally unique set of learners—one that takes into account the cultural aspect of the *Iraya Mangyans*.

These experiences with schools, teachers, and learners, have prompted me to revisit and problematize the ideals of good education, particularly putting into question the notion of universal science education. Although Biesta (2009, p.41) did not give a direct answer to what constitutes a "good" education, he posits that the purpose of education may be related to the quality of what he calls "subjectification". Good science education is judged based on how it promotes the development of a person and can be measured by the extent of change or impact such person has caused in the society where he/she lives.

In this paper, we discussed the problems of universal science education to argue that indigenous science education is way better and more relevant than the national science curriculum. In doing so, we first explored the relationship between science and culture as well as the cultural perspective of science education. We then showed how universal science education and a national science curriculum devalue culture. From there, we proceeded with the proposition that other sciences shall be recognized as science and that mere integration to the popular science is insufficient. Lastly, we presented some implications of indigenous science education as alternative to popular science in culturally-unique educational systems and society.

Science in culture and the cultural perspective of science education

We find it necessary to start the discussion by establishing the interface between science and culture. For this purpose, we adopted a simple and common definition of culture such as the one provided by Phelan, Davidson & Cao (1991) which states that culture is a set of beliefs, expectations, values, and conventions shared by a group; it also includes language, traditions and practices unique to a group. But this definition of culture is quite limited as it fails to emphasize the place of science in the whole idea of culture. Culture also includes science. Any group or society defined by a unique culture has its science (Ogawa 1995; Snively & Corsiglia, 2000). There can be many sciences and Western modern science (WMS), the one taught in today's science classrooms and has its historic origin from Western culture is just one of the many sciences that need to be considered (Ogawa, 1995; Snively & Corsiglia, 2000; Eijck & Roth, 2007). Ogawa (1995) even identified two other sciences other than WMS. These are the personal and indigenous sciences which refer to the personal and cultural level sciences, respectively. The science practiced by a particular group or society is shaped by the expectations, values, traditions, language and beliefs shared by its members. Science is enriched by realities unique to each geographical subdivision. Indeed, culture informs science.

Now, viewing science as a mere part of culture is but too simplistic. A society practicing the same science may have shared beliefs, traditions, norms, values, and conventions. Using Phelan, Davidson, & Cao's (1991) definition of culture, science is indeed culture in itself. Thus, if science is culture, then learning science, which is the primary concern of science education, is learning of culture. As Aikenhead (1996, p. 219) puts it, "cultural perspective on science education views teaching as cultural transmission and learning as culture acquisition". Gramsci (in Balampekou & Floriotis, 2012) even affirms this when he encouraged teachers to facilitate the smooth acceptance of cultures (which are acceptable across societies) among students. Science education, therefore shares the task of enculturation, making sure that cherished beliefs of a group are transmitted from one generation to the next. Culture-sensitive science education helps save culture especially in communities where younger generations have become alienated to their own culture or in societies where elders fail to do their duty on cultural transmission. Science teaching, therefore is just one of the many avenues to promote appreciation of culture.

The learning of science, which is the main concern of science education, is described by Aikenhead (2001) as a cross-cultural event. It brings students to undergo several cultural border crossings. That is, students are moving from one subculture to another. For instance, before learning classroom science, students may shift from their "already known science" in their homes and communities to a new perspective of science in school. In other words, in the process of learning science, a student has to cross from their everyday world to the world of school science.

Cultural border crossing is an important concern because it can be disruptive when not properly negotiated. When science is presented in a situation that is familiar or fit to students' beliefs and values, cultural transmission such as learning of science is supportive (Aikenhead, 1996; Hodson, 1993). On the contrary, science that is presented in a completely strange context is disruptive—it will either replace or devalue the existing beliefs and values and requires a lot more time and effort to happen.

What we are trying to convey here is that, culture and science must go hand-in-hand in the classroom. The cultural border crossing, which I find necessary in learning science, can only succeed if science is presented in a way that is congruent with students' beliefs and value systems.

The drawbacks of universal science education

Universalism as a philosophical concept is commonly applied to something that has a universal application or scope, and a universal concept or idea is regarded as "standard", "uniform" and independent of culture, ethnicity, class or race (Stanley & Brickhouse, 1994). It is the philosophy behind "universal education", "universal science" and "universal science education". In this section, we will focus on the universality of education as well as of science and its emerging field, science education. We will also lay down some criticisms on the three concepts mentioned above.

Countries which share the belief that education is a tool or instrument for national development offer free or state-sponsored schooling. They even regard it as constitutional right of its citizen. Universal education, which is an example of an educational system promoted by a state, upholds the idea that all children, irrespective of needs should be educated in mainstream schools (Cigman, 2007; Paquette, 1995). Despite its wide acceptance, universal education is never exempted from strong objections. One of its strong criticisms came from the philosopher Robert Lewis Dabney (1820-1898). As cited by Simpson (2006), Dabney believed that universal schooling does not necessarily educate people and that literacy, which most democracies consider as the primary aim of education, is not the only means of education. He also raised concern about the fact that universal education is given free. He fears that since it is provided for free, people may not find it valuable or children and parents alike may not take it as a serious enterprise. He further argued that any kind of education which comes with some "universal" flavor is "*not a blessing but bane to the cultural norms of a nation*" (Simpson 2006, p. 52) and more likely results in cultural degradation, and to some extent, cultural disintegration.

Science or Western Modern Science (WMS) as it is "officially" called is charged with being universal. Stanley and Brickhouse (1994, p. 390) puts the universalist view of science this way: "the ontological physical world itself judges the validity of a scientific account of that world, and this account is unrelated to such things as human interest, culture, gender, race…". This view reflects the "exclusivity" of science. It appears that science exists in an independent world, completely devoid of any externalities. It is as if science will forever be free of cultural influences or contamination. Likewise, it considers "creation science" as non-science and indigenous knowledge as second-class knowledge. Behind this belief is also the regard of WMS as the "only" science (Ogawa, 1995; Hodson, 1993; Cobern & Loving, 2000) or "superior" science (Lewis & Aikenhead, 2000; Van Eijck & Roth, 2007).

The issue of the "exclusivity" of Western modern science revolves around the idea that science detaches itself from society which to us is impossible. As pointed out earlier, science is part of culture and culture in itself. Exclusivity also limits social participation. It makes science available only to a select few, contrary to Gramsci's (in Balampekou & Floriotis 2012, 291) call for the abolishment of social structures. To think that WMS is supreme over non-WMS is the same as accepting Western culture as more superior than the culture of the rest of the world. Cobern and Loving (2000, p. 52) even suspect that this view may promote "epistemological hegemony" and "cultural imperialism". We are worried on this because just like Gramsci (in Balampekou & Floriotis, 2012), we are convinced that the aim of science should not be the promotion of a single ideology. Science, by all means, must be geared towards meeting social needs. Another reason why separating science from culture is impossible is the mere fact that the label Western modern science itself signifies that it embodies Western (Ancient Greek and European) traditions and culture. WMS in itself is culture-laden. In the same fashion, people who do science (not limited to scientists) have their culture which would surely influence what they do. In fact, people who are bound by their respective cultures should not be detached from science for they are the ones who make science (Balampekou & Floriotis, 2012). Regarding WMS as superior is an admission that other sciences exist and thus, invalidates the claim that WMS is the only science. This suggests then that there are other sciences which at the moment we would like to temporarily label as non-Western modern science (as we have already mentioned, every culture may have its science).

Having presented some problems attached to universalism in science, we just want to clarify that our intention here is not to devalue WMS. I believe that its methods and products were able to advance society but what I have argued so far is that universal science is problematic because it ignores the role of culture in the discipline.

Insofar as science education is concerned, we do agree with Aikenhead (1996) that the main problem about "universality of science education" lies on the assumption that science is the same from one science classroom to another, that it addresses issues and problems of students irrespective of culture. Another problem is that it gives a standardized assessment to all students even if they were not taught the same way. At a closer look, universal science education is disrespectful of students' cultural backgrounds. It even violates students' right to getting meaningful and more relevant science instruction. This led us to conclude that universalism is not only an epistemological issue but a moral issue as well.

The problem of a national science education curriculum

In spite of the strong criticisms against universal science education, it still appears that countries across the globe thru their ministries of education, implement a national science curriculum. This national curriculum, as claimed by its framers, embody the "essentials of science education" which every student should learn. It imposes content standards and competencies which every student, regardless of interest and situations should master or demonstrate. This "universality" of a national curriculum is indeed problematic as shown in the concerns that we are laying down in the following discussion.

Consistent with the Universalist approach, a national science curriculum leads to compulsory education. This setup is problematic because it violates the primary requirements for schooling which Dabney identified as aspiration and desire. For him, an unwilling student is more likely to have less appetite for knowledge. A national curriculum is also viewed as a policy that every citizen has to comply. It compels students to learn its content even if they do not want to. What is even more tragic about this set-up, as Dabney has pointed out, is that uninterested children are forced to join those who have serious desires to acquire proper education. He fears that the setup will create an unhealthy, chaotic and miserable environment for children. Thus, Dabney warned against this type of schooling that promotes crime and encourages social rebellion. As we see it, Dabney is trying to point that compulsory education in the guise of a national curriculum suppresses freedom which when taken away from a person or group often leads to turmoil.

A one-size-fits-all curriculum which the national science curriculum is trying to assume is not the perfect answer to the students' unique learning needs and context. As early as seventh grade, students may already have a career choice. In a class of forty, we are pretty sure that at least ten different career choices would emerge. How can a uniform or single science curriculum will then be able to prepare students for these different careers? Should a student who wishes to become an engineer be given the same science as the one who wants to become a sociologist? The curriculum developers may tell us that students irrespective of career choices must acquire the same, basic science content. But we don't think this answer addresses our questions head-on. Even if students with different interests need to be exposed to the same content, they always need a different approach. We are not sure if a student who is inclined in the social sciences will ever be interested to learn physics using a mathematical approach. In fairness to the national science curriculum, they now "encourage" the use of differentiated instruction or practices to address students with different needs (Tobin & McInnes, 2008; Tobin & Tippett, 2014). However, teachers do not implement this setup in the classroom for some obvious reasons. First, the word "encourage" is not compelling. Second, differentiating instruction is an added workload for teachers and requires more time for preparation and research. Third, due to time constraints, the teachers may not be able to cover all the prescribed topics in the curriculum and students may not be able to pass the national assessment. This shows that the implementation of the national science curriculum is less sensitive and adaptive to the actual learning needs of students and it continues to cling to its universal nature.

The fact that the national science education curriculum is crafted by a commissioned group of experts to determine what students should learn in Science also makes it problematic. To echo the concern of Gramsci (in Balampekou & Floriotis, 2012), these group of experts do not represent the society. Science must elaborate and use the realities of the society rather than just from a chosen few. Regardless of qualifications, these experts have personal interests to protect and are subject to their own biases. They may also be influenced by their institutional and political affiliations. More than anything else, they have a different set of values and ethics that will always dictate their decisions and actions. Moreover, Apple (1993) posits that any curriculum cannot be neutral. It is a collection of knowledge identified by a group as legit and official. Given this, a national curriculum can be dangerous. The danger, as Apple pointed out, is that by allowing the culture of the few to be incorporated into the national curriculum, it is like giving them the permission to become the moulders of people. It may also perpetuate superiority of some groups over others in society. For instance, some schools could emerge as class schools which are reflective of that particular social structure/s represented by the group of curriculum framers. What seems to be ideal according to Apple is a curriculum that responds to the culture and histories of the general populace.

In this section, we have just argued that universal science education or a national science curriculum is defective. A science education that has a cultural flavour is better (Aikenhead, 1996; Simpson, 2006; Apple, 1993) than a "universalist" curriculum.

Giving other sciences a chance

In criticizing the Universalist view of science education, cultural relativists consider multicultural science education as the saving grace. All through these years, we consider multicultural science education as science teaching that integrates culture. However, after a thorough reading of its literature, our initial impressions were proven wrong. We have also found out that even cultural relativists do not articulate the same understanding of multicultural education (as expressed by Hodson, 1993). Given the various views towards the idea, we find the analysis of Ogawa (1995) useful in forwarding our intention for this paper. He argues that “multicultural” simply means “many cultures” (p.584). Since every single culture has its science (as mentioned in the previous sections), then, “many cultures”, means “many sciences”. Based on this logic, he equates “multicultural” with “multiscience”. He also identified three types of sciences, namely: indigenous, personal, and Western modern science, and asserted that multiscience perspective science education is more sensible than the highly embraced multicultural education.

Multiscience perspective science education is but a promising and worth elaborating discourse, which we will try to partially tackle here. To begin with, multiscience perspective science education does not consider itself a “panacea” to solving science education problems. It does not even push for the merging of all kinds of sciences into just one science nor it subsumes or devalues other sciences as mere superstitions which the WMS tends to imply. The WMS’s recognizes the existence of other sciences and their contribution to the society, but it does not consider them as its equal. Multiscience perspective science education removes the “exclusiveness” and “superiority” labels of science believing that they are impossible, unrealistic, hegemonic and disrespectful of cultural diversity. Simply, it accepts other sciences as “science”. In essence, multiscience perspective science education gives other sciences a chance to be recognized or treated as “science” which to us is a significant step in advancing the ongoing universalist-relativist debate on how science education should support cultural diversity. It should also be clarified that multiscience perspective science education does not devalue WMS. It does not even say that WMS is bad or wrong nor intend to replace or displace it. It simply addresses the basic issues of universal science education as reflected in WMS.

While we agree with Ogawa (1995) on the acceptance other sciences, we can only move for the acceptance of indigenous science which includes a subset called Traditional Ecological Knowledge or TEK (Snively and Corsiglia, 2000). Personal science, to us, is not necessarily another science contrary to Ogawa’s (1995) claim, but is just part and parcel of indigenous science. As mentioned earlier, indigenous science is unique to a certain culture and is derived from local or community-based knowledge that helps communities thrive. TEK, on the other hand, is "the science of long resident oral people and a biological sciences label for the growing literature which records and explores that knowledge" (Snively & Corsiglia, 2000). The *Mangyans* of Mindoro, Philippines, for instance, have their indigenous science and their "kaingin" system is just one of their many TEKs.

What is clear at the moment is the recognition of the two sciences: Western modern science and indigenous science. WMS has already a well-established methods but indigenous science still needs systematic organization as a discipline.

Implications of Indigenous Science to Science Education

With the recognition of indigenous science as "official" or "legitimate" science, and as equal to WMS, science teachers, especially those who want to present science education in a cultural perspective, will be encouraged to use indigenous science as a "pedagogical stepping stone" (Snively & Corsiglia, 2000). It will help facilitate cultural border crossings (Aikenhead 1996; Aikenhead, 2001) that anthropologists consider important in the learning of science. It will make the learning of science better as it requires less cultural border crossing compared to WMS. Learning science is no longer a cross-cultural event but it is an avenue for learning one's own culture.

Adoption of indigenous science in the classroom creates in mind an interactive, informal, and reality-driven learning atmosphere. Students would talk about science in their own language and discuss the science behind the things around them and in the different phenomena observed in their community. It uses the community as the context of learning, in every lesson. It does not pressure students to perform experiments that verify some laws and theories. Rather, it encourages students to conduct research on how to solve basic community problems and issues.

While implementing indigenous science preserves the function of school as a social institution, it also introduces a radical change in the structure of the educational system. It promotes cultural transmission and helps in preserving diminishing cultures. Under this setup, the community should be tapped as a learning resource and a venue for experimentation. Community people may serve as resource persons, teachers, para teachers and collaborators. With indigenous science, science education becomes a collaborative enterprise. Nevertheless, it will make national curriculum, national testing/assessment, standardized criteria for hiring teachers and many other national standardization mandates irrelevant.

Conclusion

We wrote this paper in the light of some personal experiences that reflect the deficiencies of a universal or national curriculum. To trace where the problems lie, we explored the relationship between science and culture and cultural perspective of science education, universality of education, science and science education, national science education curriculum and identified some ways to address glaring gaps. We also revisited some discourse on multicultural education which enlightened me about some possible reasons for the failure of the implementation of a certain curriculum that tries to integrate indigenous knowledge (multiculturalism). We went on and realized that to advance the discussion about the universality of science and the issues associated with it, coming up with a more liberal definition of science makes sense. For instance, describing science as "a rational perceiving of reality" (Snively & Corsiglia, 2000) invites other forms of knowledge to qualify as science. We appreciate the multiscience perspective science education of Ogawa (1995) and elaborated it. Eventually, we came up with the suggestion of looking at indigenous science and the popular Western modern science as equal sciences which are not mutually exclusive and may be used simultaneously in a science class.

Thus, the main contribution of this paper is to lay down significant rationalizations on the adoption of indigenous science education as a classroom science. Compared to Western modern science, indigenous science education requires less cultural border crossings and hence, facilitates better learning of science. It likewise gives teachers an alternative form of classroom science. It also respects students' right to be educated in the context of their own culture and helps society in its cultural transmission function. Most importantly, it debunks superiority and hegemonic labels of science which I think is necessary in the attainment of a just and peaceful society. Indeed, proper and systematic implementation of indigenous science education has a lot to offer for the improvement of teaching science.

References

Aikenhead, G. S. (1996). Science Education: Border Crossing into the Subculture of Science. *Studies In Science Education, 27* (1). 1-52. DOI: 10.1080/03057269608560077.

Apple, M. W. (1993).The Politics of Official Knowledge: Does a National Curriculum Make Sense? *Discourse: Studies in the Cultural Politics of Education, 14* (1), 1-16.

Aikenhead, G. (1997). Toward a First Nations cross-cultural science and technology curriculum. *Science Education, 81*(2), 217-237.

Aikenhead, G. (2001). Integrating Western and Aboriginal Sciences: Cross-Cultural Science Teaching. *Research in Science Education, 31*(3), 337-55.

Balampekou, M. & Floriotis, G. (2012). Antonio Gramsci, Education and Science. *Journal For Critical Education Policy Studies, 10*(1), 285-297.

Biesta, G. (2009). Good Education in an Age of Measurement: On the Need to Reconnect with the Question of Purpose in Education. *Educational Assessment, Evaluation and Accountability, 21*(1), 33-46.

Cigman, R. (2007). A Question of Universality: Inclusive Education and the Principle of Respect. *Journal of Philosophy of Education, 41*(4), 775-793. doi:10.1111/j.1467-9752.2007.00577.x

Cobern, W. W. & Loving, C. C. (2000). Defining 'Science' in a Multicultural World: Implications for Science Education. *Science Education, 85*(1), 50-67.

Eijck, M. V. & Roth, W. (2007)., Keeping the local local: Recalibrating the status of science and traditional ecological knowledge (TEK) in education. *Science Education, 91*(6), 926-947.

Hodson, D. (1993). In search of a rationale for multicultural science education. *Science Education, 77*(6), 685-711.

Lewis, B. F. & Aikenhead, G. S. (2000). Introduction: Shifting Perspectives from Universalism to Cross-Culturalism. *Science Education, 85*(1), 3-5.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583.

Paquette, J. (1995). Universal education: Meanings, challenges, and options into the third millennium. *Curriculum Inquiry, 25*(1), 23.

Phelan, P., Davidson, A. & Cao, H. (1991). Students' multiple words: Negotiating the boundaries of family, peer, and school cultures. *Anthropology and Education Quarterly, 22*(2), 224-250.

Simpson, B. D. (2006). Cultural degradation of universal education: The educational views of Robert Lewis Dabney. *Journal of Libertarian Studies, 20*(3), 47-60.

Snively, G. & Corsiglia, J. (2000). Discovering Indigenous Science: Implications for Science Education. *Science Education, 85*(1), 6.

Stanley, W. B. & Brickhouse, N. W. (1994). Multiculturalism, Universalism, and Science Education. *Science Education, 78*(4), 387-98.

Tobin, R. & McInnes, A. (2008). Accommodating differences: Variations in differentiated literacy instruction in Grade 2/3 classrooms. *Literacy, 42*(1), 3–9.

Tobin, R. & Tippett, C. D. (2014). Possibilities and Potential Barriers: Learning to Plan for Differentiated Instruction in Elementary Science. *International Journal of Science and Mathematics Education, 12*(2), 423-443.

Sustainable Development from Past to Present

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Introduction

Our planet is the product of an evolutionary process that has continued for millions of years. With the emergence of human beings at the end of the formation stages of our planet, the history of mankind has begun. In this context, human-nature relationship has started simultaneously with human existence in the earth. Throughout human history, human-nature relationship has continued in various ways. People have been in a relationship with their environment throughout their entire life since their creation. This relationship has continued in various ways in accordance with the needs, demands, and expectations of people. In the early times, in the relationship between the environment and human being, the environment was the strong side. Because human beings were in need of environment to meet their needs and survive. Therefore, they were weak and powerless in the face of the environment. However, as time passed, this relationship turned to harm the environment with the change and development of mankind over time, and the desire to dominate the environment in line with the changing needs and demands of people (Altınışık, 2016; Özerkmen, 2002).

From the time of their existence, human beings meet their needs such as hunting, finding food, sheltering and dressing from the nature. The relationship between human and the nature was based on the provision of vital activities. But with the advancement of time, as a results of the change of people's needs and expectations, the desire to have more luxurious living standards, and the competition between countries and societies, the relationship between human and the nature has turned into a ruthless use of the environment, which only one side would benefit for a certain period of time. Especially with the industrial revolution and noticing that the results of the steps taken for industrialization threatened human health and risked the future by forcing the capacity of the planet, taking measures to stop this bad course has become mandatory. Although the steps taken in the name of modernization and industrialization using the nature and resources unconsciously provide short-term welfare, but in the long-term, it is understood that it is very risky for the future of humanity. As environmental problems started to threaten the livability of the planet, the environmental problems and their impact on public health had to be addressed on a global scale (Yeni, 2014; Alagöz, 2004).

In the twentieth century, the rise of environmental damage to the upper levels caused by unconscious steps in the name of development under the influence of the rapid growth of population with industrialization and urbanization brought the concerns about human health and the future of the world. As a result of the destruction of natural life and the unconscious use of resources, food and water shortages and, consequently, many fatal problems such as hunger, disease, and poverty began to emerge in some regions around the world. In addition, the melting of glaciers, changes in the climate, destruction of the ozone layer, and global warming to a serious extent have started to threaten the world today and tomorrow. With the emergence of these problems, it has been recognized by all the societies in which the self-renewal capacity of the world has been damaged. In the case of continuation of this trend, the world has begun to search for solutions as soon as it is understood that it will lose its character of being a habitable planet. In the absence of measures to address these problems, solutions have been started to be searched on a global scale as a result of realizing that it will threaten the whole world over time. By understanding that the solution to these problems can only be found if every individual, every society, and every state in the world act together in cooperation by taking certain responsibilities, the states have come together in international conferences and started to produce solutions. The concept of Sustainable Development has come to the fore as a result of the efforts made for the protection of our planet today and tomorrow (Ulusoy & Vural, 2001; Altunbaş, 2003; Karabıçak & Armağan, 2004; Başol, Duman, & Çelik, 2005; Baykal & Baykal, 2008).

Sustainable Development

Sustainable development; is a matter of different disciplines which is formed by the combination of sustainability and development concepts.

Sustainability

The concept of sustainability; is a concept used for many areas such as environment, economics, education, the use of natural resources and energy resources, national and international government policies, production, and society. As a concept, sustainability for the first time was included in the World Charter for Nature document, which was adopted in 1982 by the International Union for Conservation of Nature (IUCN). Sustainability in this document; was expressed as the most appropriate way to sustain the ecosystem, land, water and atmosphere sources and organisms that individuals benefit from throughout their life and to carry out the process of sustainability without harming the ecosystems (Yavuz, 2010).

Sustainability in the general sense; is the continuity capacity of a condition or phenomenon. Therefore, the concept of sustainability is a concept that expresses the process because the ecosystem concept is meant to ensure that people benefit from many phenomena such as atmosphere, water, and land resources for generations (Eryılmaz, 2011).

Development

Development concept as meaning; can be expressed as growth, modernization or structural change to a better state. Development is not a change, activity or social development in any area. As known, individuals and societies are constantly developing and changing depending on changing conditions of the world. Social structure, customs and traditions, beliefs, attitudes and behaviors of individuals, and social values and norms are in a continuous change depending on time. Therefore, the concept of development has a very wide field of influence and can be defined as all of the interventions to improve the change and development processes in a positive way.

In other words, development is all of the attempts to get a better state than the current state of individuals or societies. It is a wide-ranging concept that covers the whole of the efforts made for the positive development of the economic, social and cultural structures of societies (Tolunay & Akyol, 2006).

Definition of Sustainable Development

Mankind has maintained his life in relation with the environment from his existence until this time. From the first age to this time, people have met their needs from the nature. As time went by, with the advances in technology and science, people have used nature generously in the way of achieving the level of advanced civilization. Depending on the requirements of the era with the increase in population, this usage amount has reached the highest level. However, the nature also has a capacity. As a result of the unconscious use of the resources used for living in better standards, the non-renewable nature of some resources, the destruction of resources as a result of unconscious use, and even the consumption of them, an unhealthy and improper environment not suitable for living has been created in many parts of the world (Engin, 2010).

The number of people living on earth is increasing day by day. The number of people living in the world in 2050 is expected to reach 9 billion. The increase in the number of people means the need for resources to meet housing, nutrition, care, education, and job opportunities. When the growth rate of the world population is examined, the rise in the amount of increase stands out in the last century. The rate of increase that was 0.65% in the 1900s has reached 2.09% in 1970 and 1.70% today. The increase in the production and consumption activities brought by the rapid population growth pushes people to consume more natural resources. Problems such as environmental pollution, industrialization, distorted urbanization, and so on are some of the problems that rapid population growth caused. Today, around one billion people worldwide face poverty, unemployment, and hunger problems. In addition, a considerable number of people have been deprived of the right to education, which is a basic need, for various reasons. This number is rising in proportion to the increase in the world population. These and similar problems, which prevent society from living in prosperity, caused the concept of sustainable development to be on the agenda. (Sarıçoban, 2011).

Sustainable development is a concept that has debates on its definition due to its wide range of meaning. Since the sustainable development has been adopted by many masses such as governments, large enterprises, companies, social reformers and environmentalists etc., the field-centered definitions by each audience have been made (Giddings, Hopwood, & O' Brien, 2002).

Although there are many definitions of sustainable development, the most valid definition is defined in 1987 in the Brundtland Report of the World Commission on Environment and Development. In this report, sustainable development was defined as meeting today's needs in a way that does not eliminate the capacity of the next generation to meet their needs (Brundtland Report, 1987).

Dimensions of Sustainable Development

When we look at the definitions of sustainable development, international texts, and sustainable development approaches, sustainable development has three dimensions: economy, environment and society. Only the development of the economy, society or the environment does not express sustainable development. In order for sustainable development to take place, people must live in a healthy environment, in economic prosperity, and social equality. For the realization of sustainable development, the sustainability of these three dimensions must be ensured simultaneously (Sandel, Öhman, & Östman, 2006; Alkış, 2007).

Environmental Sustainability

Environment is a setting in which living and nonliving beings are connected to each other by various relationships, they interact and are influenced by each other. The environment is a structure that contains both living and nonliving elements. While the living beings of the environment can be plants, animals, microorganisms, people, the nonliving beings of the environment can be soil, air, water, climate, underground resources that is living things except everything. The environment is not a static structure. On the contrary, the environment is a dynamic structure that contains living and nonliving elements and is affected by social, cultural and physical changes. Environment is the whole of interactions and relationships between people with other people, people with plants and animals, living beings nonliving beings such as air, water, underground resources, climate and so on (Ak, 2008).

Since its existence, humanity has lived in a relationship with the environment. This relationship was initially in the form of meeting the needs such as nutrition, shelter or protection. The center of the human-environment relationship was in the form of meeting the vital needs of man, but as time progressed, the shape of the human-environment relationship changed. Until the industrial revolution, the impact of people on the environment was not destructive. With the effects of economic developments, urbanization, and industrialization, environmental pollution increased to higher levels. Over the years, many factors such as technological developments, population growth and unplanned urbanization have increased the impact of human on the environment to destroy natural life. This destruction has not only limited the ability of nature to renew itself, but also began to threaten life of living beings (Aslan & Çınar, 2015).

Many reasons such as the loss of livability of the world, environmental pollution causing to deaths, global warming, and climate change have led people to take measures. In the 1950s, some work was initiated to stop this miscarriage. The concept of sustainable development has emerged in this search for solutions. The environmental sustainability, which is one of the three dimensions of sustainable development, needs to be ensured for the realization of sustainable development.

Sustainability of the environment is that we can leave the next generations in a more livable environment by improving the environmental conditions that we have. This is only possible with less environmental damage (Alkan, 2015). Some of the actions required to prevent environmental damage and ensure the sustainability of the environment are listed below:

- Protection of natural resources,
- Biodiversity and protection of endangered organisms,
- Reducing the concentration of carbon dioxide in the atmosphere as a result of the use of nonrenewable energy sources and motor vehicles,
- Widespread use of renewable energy sources,
- Reproduction of green areas,
- Prevention of environmental pollution (water, soil and air pollution),
- To ensure that waste is recycled, thus reducing the use of raw materials,
- Preventing climate change, which is the most significant impact of global warming by taking serious measures for global warming,
- Supporting environmental oriented activities by increasing the number of

environmental organizations

- Minimization of ecological footprint, (Dinç, 2015; Tosunoğlu, 2014; Ergün & Çobanoğlu, 2012; Koçak & Balcı, 2010; Özçuhadar, 2007; Toprak, 2006; UNESCO, 2006).

Environmental sustainability can be expressed in general as that the speed of consumption of natural resources should be slower than the speed of self-renewability of the nature and that the practices that harm the natural life are kept under control. The number of people living in the world is increasing day by day and the increase in the use of natural resources in line with this increase is an obstacle for the sustainable environment. For this reason, natural resources should be protected and the consumption rate should be kept at a level that will not exceed the rate of self-renewal.

The vast majority of people provide their energy needs from fossil fuels such as coal and oil. As a result of the use of fossil fuels, various toxic gases accumulate in the atmosphere. Particulate matter and toxic gases accumulated in the atmosphere due to the use of fossil fuels and motor vehicles cause respiratory diseases, lung problems, cardio problems, cancer and even death in individuals (Karakaş, 2015).

The accumulated gases in the atmosphere due to the use of fossil fuels and motor vehicles not only affect human health, but also disrupt the balance of natural life. Especially after the industrial revolution, the greenhouse gases such as CO_2, N_2O, and CH_4 that's concentration has been highly increased in the atmosphere increases the surface temperature due to the excessive greenhouse effect. Global warming as a result of the increase in earth temperature is a serious threat to the future of the world. Global warming causes climate changes. Extreme weather temperatures in different regions of the world, melting of glaciers and hence the rise of sea and ocean levels, heating of sea and ocean waters and damage to the aquatic ecosystem, extreme temperature in one part of the world, floods and storms in another part of the world, the extinction of the plant and animal species that are endangered due to climate change caused by global warming, are just a few of the damages of global warming. Therefore, renewable energy sources (solar energy, geothermal energy, etc.) that we call clean energy sources found in natural life should be used instead of fossil energy sources (coal, oil, natural gas) as a requirement of a sustainable environment (Sever, 2013; Akın, 2006)

Water, soil and air pollution to reach harmful dimensions prevent environmental sustainability. These sources, which are polluted for many reasons such as waste, industrial enterprises, also threaten the health of living. Recycling policies should be implemented to end waste pollution. Recycling of waste will reduce resource use for raw materials and prevent environmental pollution and therefore many problems caused by environmental pollution (Korkmaz, 2015).

The sustainability of forests is very important for the sustainability of the environment. Nowadays, forested areas are destroyed by many reasons such as pollution caused by enterprises, firewood supply, grazing, mining activities, and forest fires caused by people's deliberate or careless behavior. Destruction of forests means destruction of natural life. In addition to providing oxygen and raw materials, our forests are the sine qua non of a healthy world with many other benefits such as preventing global warming, preventing air pollution, preventing erosion, protecting biodiversity, providing job opportunities, making life healthy, and preventing disasters such as floods, landslides etc. Therefore, conservation of our existing forests planting trees should be supported on a global scale (Sever, 2002; General Directorate of Forestry, 2017).

Another important issue for the sustainable environment is the ecological footprint. The ecological footprint is expressed as the amount of fertile water and land needed to compensate for the resources and wastes that people use throughout their lives, or the amount of productive space people use throughout their lives. When the definition of ecological footprint is considered, it is seen that the concept is based on the carrying capacity of the world and the main purpose is to ensure the continuity of the environment (Ünal & Bağcı, 2017).

The importance of environmental organizations for a sustainable environment is indicated by the Agenda 21 published in the Conference on Environment and Development in Rio de Janeiro in 1992. Environmental organizations play a very important role in addressing environmental pollution and other environmental problems and in solving these problems. As a result of the activities of these organizations, raising individuals who are aware of environmental problems and taking an active role in the solution of environmental problems is very important in terms of ensuring sustainability because sustainable development can only be realized when all individuals are involved in economic, social, and environmental sustainability activities (Uzun & Sağlam, 2007).

Social Sustainability

Society is the whole of the relationships formed by a large number of people who maintain their existence for a certain period of time at a known physical environment, engage in activities to meet the necessary requirements for the survival, constantly interact with each other and the environment in which they live, and take roles in the forming and sharing process of a common culture. A general definition is the community of individuals living in a certain location, with a valid written legal system of its own, covering many sub-social groups, and with a unique economic system. In a nutshell, society is a community of people who have existed for a long time, who exist in a certain region and share a common way of life (Aslan, 2001).

Social sustainability, which is one of the three main dimensions of sustainable development, is the capacity to provide welfare, security, health and education to every individual in society without any social class or gender discrimination. The meaning of social sustainability for a region is the capacity to support the effective communication of different stakeholders with each other and the aim of achieving the same objectives at all levels through the close relationships of institutions and organizations. Sustainable societies occur only when formal and informal processes, systems, structures, and relationships promote the creation of healthy and livable communities in today's and future generations (UNESCO, 2006; Hürol, 2014).

The necessity of social sustainability is to ensure that all individuals living in the world have equal rights such as health, education, justice, shelter, freedom and other social services regardless of language, religion or gender. Sustainable societies are productive, healthy and determined societies where all individuals live in prosperity. However, although societies who have income distribution disparity, unrest, and health problems seem to have experienced short-term relief or recovery with some temporary solutions, sustainable societies that are necessary for sustainable development cannot be provided unless this improvement is continuous (Türer, 2010).

In sustainable societies, each individual should have equal income distribution and living standards. In this context, poverty is the biggest problem that prevents the sustainable development in social dimension. For this reason, a development movement that does not eliminate poverty is not sustainable. Of course, poverty is not the only problem. Many problems such as lack of education, unemployment, problems in the health system, and unreliable residential areas hamper the creation of sustainable societies. For social sustainability, these problems need to be eliminated by permanent solutions (Aydoğan, 2010; Kara, 2017).

In order for the society to be sustainable, the living standards of future generations are at worst as the living standards of the people who are living at the moment. Some of the opportunities that should be provided to all individuals for a sustainable society are listed below.

For all individuals;

- Ensuring gender equality and social justice,
- Equal treatment of each individual regardless of language, religion or race,
- Ensuring the right to health and education,
- The right to safe and peaceful life,

- Establishment of healthy settlements,
- Taking responsibility at the social level to increase the welfare level of individuals,
- The right to benefit from social services,
- Ensuring the cultural diversity.

Social sustainability is to increase the welfare of every individual in society and thus to benefit from individual potentials in full efficiency because the success of societies is directly proportional to the personal success of each individual. Social development means investing in people. For this reason, all the obstacles that cause the development of individuals need to be removed because only people who guarantee quality of life can serve the society more productively. Every individual has the right to grow in a safe environment, to have the opportunity to develop his/her skills, to have a good education, and to benefit from health services equally with all other individuals. Only when these conditions are fulfilled, individuals can meet their needs, and if they have a profession with sufficient income, they can be beneficial to themselves, their families and thus to society and thus social sustainability can be achieved (Altuntaş, 2012; Özmete, 2011; Hoşkara, 2007; Atıl, Gülgün, & Yörük, 2005).

The productivity of societies is very important in the realization of sustainable development. The productivity of the societies depends on the productivity of the individuals who make up the society. Therefore, the social functioning of individuals should be increased. For this reason, society has responsibilities other than providing a safe place to live. Day cares and nurseries where children of working parents are well looked after and begin their initial education, nursing homes and orphanages established for the survival of the elderly and orphans, and providing home care services for individuals who are sick and handicapped are the responsibility of communities. In addition to this, the child protection institutions established to raise the children whose parents have died or are not economically qualified to meet the needs of their children and social assistance and solidarity institution that provides financial support to the individuals whose financial status is not sufficient are of great importance for sustainable societies as social services provided by governments (Economic and Social Inclusion Corporation).

The importance of social services is also very important in the creation of sustainable societies. Many services such as dormitories, scholarships, credits, youth centers established in provinces and districts, vocational training courses provided by local authorities for students and family counseling, mother-child health and family planning centers, and disabled care and rehabilitation centers fulfill the responsibilities of administrations and are very important for high welfare and sustainable societies.

Social justice is the equal distribution of existing values to all individuals in the society without discrimination of language, religion, race or gender. Social justice means that all individuals benefit equally from the rights of education, health, justice, housing and social services, and not to be judged by anyone's race, belief or language. In other words, it means that all individuals in the society have equal rights and freedoms (Sunal, 2011). Social justice contributes to the sustainability of societies by eliminating negative elements such as inequality of opportunity, inequality of income distribution, and treatment by status (Çetin, 2015).

Another issue that is important for a sustainable society is gender discrimination. Gender discrimination caused by the roles that society places on women and men causes women's status to be perceived as low compared to men due to stereotypes. In many countries, limited work opportunities for women, not sending girls to school, preventing them from entering work life, and violence they are exposed to are among the situations caused by gender discrimination. There is no room for gender discrimination in sustainable societies. Almost half of the world consists of women. According to Eroglu (2004), the values given to women in societies reflect the level of development of that society. Therefore, the employment of women is very important. As women receive education and work, they will believe in their individual competences and stand on their own feet, thus contributing to the formation of a more productive society by strengthening their status both individually and in society (Tutar & Yetişen, 2009; Eroğlu, 2004).

Taking actions on a global level is essential for sustainable development. Environmental or economic crises occurring at one end of the world will affect us sooner or later. In the report titled 'The Limits of Growth' published by the Rome Club in 1972, it was clearly stated that the problems such as hunger, poverty, resource consumption, economic crisis, civil war, and population increase in different regions of the world threaten not only those regions but the whole world and it is emphasized that the world will lose its habitability, if the solution is not found (Çankır, Fındık, & Koçak, 2012).

If we think that all people live in the same world, we can understand more clearly that we have no chance of not being affected by resource consumption, poverty, hunger, and war happening in other countries. For this reason, the way to leave a livable world for future generations is that people who have different beliefs, languages and people living in different regions cooperate together for the same aim. Many events such as sports organizations, competitions, conferences, concerts all around the world enable many people with different cultures to come together, to interact and to have a common share in a global scale. Therefore, given that the only way for sustainable development is to act together, the intercultural interaction is very important (Bekiroglu & Balci, 2014).

Economic Sustainability

Before the concept of sustainable development came into our lives, the economy and the environment were seen as two independent systems. According to this idea, the environment was a system where the resources needed to develop the economy were provided. The idea that nature can be used without limits for the economy is contrary to the principle of not reducing the capacity of future generations to meet their needs that is the fundamental aim of sustainable development. Consumption increases with increasing population and resources are rapidly depleted and the world is losing its ability to renew itself. The idea that nature is an unlimited source ended with the discussion of environmental problems on a global scale, and the period in which economic growth was based on the increase in income level was closed and the economic developments started to be planned for the benefit of the environment and society (West, 2013; Çolak, 2012).

Especially in the process of industrialization, the environment has been used very brutally for economic growth. This situation caused the world to face serious health and environmental problems. The rapid growth of the environment and health problems caused by the steps taken in the name of economic growth and industrialization made it necessary for governments to come together to act at the international level, to identify problems, to take measures, and to produce solutions. One of the five documents published by the United Nations Commission on Environment and Development (UNCED) as a result of the Earth Summit with the participation of thousands of people is Agenda 21. In the Agenda 21, which is an action plan for sustainable development, it was emphasized that economic policies should be organized in the light of sustainability in order to ensure the requirements for social and environmental sustainability and thus the realization of sustainable development (Zafir, 1998; Türkel, 2011; Sarıçoban, 2011).

Some articles of Agenda 21 related to sustainable economy:

- To plan economic policies in a way that reduces the negative effects of production technologies on the environment,
- To organize ongoing production and consumption models according to sustainability,
- To plan environmental and economic policies in a way to benefit each other,
- Providing the necessary support for the development of developing and underdeveloped countries.

All growths and developments in the economy are not covered by the sustainable economy. Economic growth and sustainable economy have different meanings. The criterion in economic growth is generally the increase in income at the national level and industrialization. The gross national product (GNP), which is the equivalent of all goods and services produced within a country within a certain period of time, is an indicator for economic growth. The resources consumed for growth, the applications, and the damage caused by the industrialization to the environment and human health are not within the scope of economic growth. Sustainable economy is a system that works for the benefit of the society, takes the future generations into consideration while meeting the needs of individuals and society, not only focuses on economic growth, but also acts as a source of exhaustion of resources, and structures the production and consumption models in a way that harms the nature the least. Sustainable economic systems are based on economic growth, social welfare, and environmental damage (UNESCO, 2006; Gürses, 2009; Tandoğan & Özyurt, 2013).

The basis of sustainable economy is based on the concept of economic capability. The idea of economic capability emphasizes that developments in the economic sphere are tools used to enable people to have better living standards. The main aim for economic capability is the improvement of the current situation of the individuals and the society, that is, the welfare of the society, and the economic developments combined with the ethical rules play a role in providing this welfare in the social dimension (Gürses, 2009; Yüksek, 2010; Kaya, 2013).

Individuals have duties in the sustainability of the economy. As time goes on, societies become consumption-oriented. This situation affects not only economic sustainability but also environmental and social sustainability. In order to meet the needs of continuously consuming societies, economic systems are continuously producing and utilizing nature as a source of energy and raw materials for production. This reduces the life of natural resources and damages the environment. As the damage to the environment significantly affects the soil, air and water, as long as this situation continues, all individuals living on the earth will be under threat of famine (Hayta, 2009; Dücan, Polat, & Balcıoğlu, 2016).

In economic sustainability, it is essential to use all resources used in the process of production of goods and services with a controlled and environmentally friendly approach. Because after the industrial revolution, the world's natural resources have been quickly destroyed and consumed for many reasons such as population growth, industrialization, and urbanization. If the use of resources and environment for certain reasons continues in this way, even the existing individuals will have to struggle with many problems, let alone the future generations. Therefore, focusing only on the growth of the economy and the increase in income may provide economic relief for a while, but it will not be effective in the long term. A system that consumes resources for economic growth will lose its function when resources are destroyed or consumed. Systems should be structured on a sustainability basis if welfare, growth and development are to be permanent. This is only possible by changing the existing models of production and consumption according to the social responsibility of economic policies and the enterprises and to the principles of sustainable development in a way that enables long-term use by taking the environmental and social benefits into consideration. Only the economic development planned in this way is sustainable (Özçağ & Hatunoğlu, 2015; Hayta, 2006).

Developments in technology and science are the result of research and development (R&D) activities carried out by companies and firms. These technological products resulting from R&D activities can be purchased from the technologically advanced countries (which are not economic and continuous in the long term) and countries can produce these technologies with their R&D studies. With these innovations, countries can compete with other companies and firms on international trade platforms. Competition between firms is very important in economic sustainability. Intercompany competition leads to increased market share and profit. Since R&D studies provide competition among firms, it is very important in forming sustainable economic systems (Korkmaz, 2010).

Sustainability of the economy for sustainable development is that the economic activities meet the needs of individuals and societies in an active way by taking the interests of future generations into consideration. In sustainable economic systems, economic conditions should be structured to support the initiatives of individuals or organizations. In economic systems, governments should conduct debt management (borrowing) in a way that will not undermine the capacity of today's people and future generations to meet their needs as individuals and as a society. In addition, safe environments should be created for investors and investments, vital sectors (health, education, etc.) should be encouraged to invest, market movements should be prevented from being unbalanced and investments should be made in systems that can achieve high profits by looking out for environmental responsibilities (Özkan, 2017).

For the sustainability of economic systems, the process from the production of goods and services to consumption and even the process after the consumption should be planned within the framework of sustainability. In the production of goods and services, the resources should be used in the most economical way, the products should be made of raw materials that cause the least harm to the environment and human health, product technologies should take environment protection measures, and products should be made of as much recyclable materials as possible for the consumption and after process. Thus, recycling of waste can reduce raw material use and environmental pollution as well as increasing economic gains by recycling (Yücel, 2003).

Sustainable development fights hunger, poverty, and unemployment. Therefore, sustainable economic systems are obliged to provide income and employment to all individuals in order to ensure the sustainability of the society. Sustainable development is a global issue that needs to be evaluated together. Therefore, the sustainable economy must also exist in the international dimension. For this reason, it is very important for states to trade with each other in the framework of fair trade and to keep international trade alive with the investments in different regions (Yüksek, 2010).

As mentioned before, the environment, economy, and society are the three main pillars of sustainable development. Sustainable development cannot be mentioned unless sustainability is provided in these areas (Özsoy, 2015).

Sustainable Development Approaches

Sustainable development consists of three dimensions: society (social), environment and economy. It has 3 main dimensions:

Social sustainability is the provision of topics such as gender equality, social justice, social services, the right to health and education, the right to live safe and peaceful life, intercultural interactions, healthy settlements, and the efforts to increase the well-being of individuals as well as language, religion and racial equality and freedom for all people on earth.

Environmental sustainability is the provision of topics such as protection of natural life, protection of resources, protection of biological diversity and endangered species, reduction of environmental pollution (water, air, soil pollution), use of renewable energy sources (geothermal, wind energy etc.) instead of nonrenewable energy sources (coal, oil, etc.), conservation and reproduction of green areas, reduction of resource use and environmental pollution through waste recycling, reduction of ecological footprint, and fighting global warming.

Economic sustainability is the provision of topics such as saving of resources, income-expenditure balance, income distribution disparity inequality, sustainable production and cost, reliable environments for investments, investment in high-income sectors, investment in sectors of vital importance, and R&D activities (Kuşat, 2013; Şahin & Kutlu, 2014; Olsson, Gericke, & Chang Runghen, 2016).

The concept of sustainable development took place officially for the first time in 1987 in the 'Our Common Future' (Brundtland Report), published by the World Commission on Environment and Development. In the periods before the emergence of the concept of sustainable development, the fields of environment, economy and society were considered independently (Figure-1).

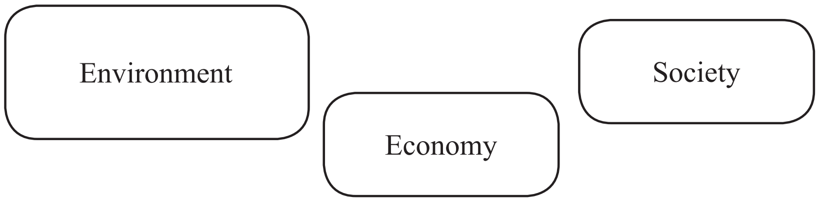

Figure 1. Separate Thinking of the Dimensions of Sustainable Development

The definition of sustainable development in the Our Common Future report, which is to meet the needs of today's people without harming the capacity of future generations to meet their needs, revealed that sustainable development is a necessity in the era of a high level of environmental pollution, social injustice, and economic inequality and that environment, society, and economics areas should not be considered independent of each other to actualize sustainable development. After the Our Common Future report of 1987, the relationship between environment, economy, and society has been began to be examined. Ideas were put forward as to the ways and the scope of the relationship between environment, economy, and society (Palabıyık, 2009; Gürlük, 2010).

One of these ideas is the approach that the element of society encompasses the element of economy and the element of environment encompasses the element of society. According to this approach, the economy element cannot exist without the elements of society and environment, the element of society can continue its existence independently of the economy, and the environment element can continue its existence without society and economy elements.

This approach is also known as the 'Russian Doll Model'. Looking at the model, although economic element seems to be the center of the sustainable development, this does not mean that it is the most important factor. On the contrary, while the economy element is dependent on society and environment elements in the model, the environment element is able to continue without them even though it covers by society and economy elements. In other words, the Russian Doll Model is an economy-centered approach within the boundaries of the environment. The total of the figure refers to sustainable development (Levett, 1998; Figure-2).

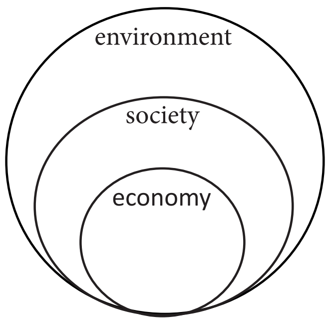

Figure 2. Russian Doll Model

Another model that tries to explain the relationships between the dimensions of sustainable development is the model which is accepted today as the three pillars supporting each other and which looks like a Venn diagram when looking from the top. The original name of the model is Three Pillars (People, Planet, Profit).

This model is also known as the Three E's Balance Rule. Three E in the Three E's Balance Rule is called: Environment / Ecology, Equity / Equality and Economy / Employment (Hürol, 2014; Figure-3).

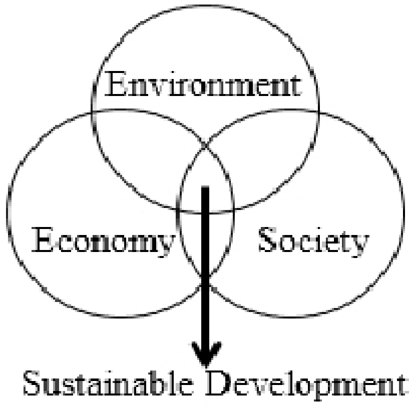

Figure 3. Three Column Model

In the three-column model, the intersection of environment, society and economy clusters is the point of sustainable development. Looking at the model, it is seen that the environmental, economic and social dimensions have an equal impact on sustainable development. According to the three-column model, sustainable development is made possible by the simultaneous provision of economic, social and environmental sustainability. In sustainable development, economy, environment, and society are the dimensions that affect each other in an interaction. In the three pillars model, the three main dimensions of sustainable development are in a balance. In the model, environment, economy, and society dimensions are given separately but interrelated. The intersection of these three dimensions represents the point where they work together for humanity and this is where sustainable development takes place. That is, sustainable development can take place when they achieve the simultaneous sustainability of the three dimensions (Manzi, Lucas, Lloyd Jones, & Allen, 2010; Akgül, 2010; Özmehmet, 2008; Thwing.org).

Historical Development of Sustainable Development

The concept of sustainable development emerged as a result of realizing increasing environmental and health problems, poverty, inequality, injustice, humanity's concerns about a healthy future along with the problems of socio-economic issues, and that the current situation does not promise a positive future for a livable world (Hopwood, Melor, & O'Brien, 2005).

In his book Silent Spring, which was written in 1962 by Rachel Carson, first signals were given that sustainable development is a necessity. The book emphasized that the negative effects of human activities on the nature continues to grow more and that in the event that the damage to the nature progresses rapidly, all resources will be polluted and even exhausted and the world will become unfit for living conditions (Dinç, 2015).

The foundations of sustainable development were laid in 1972 at the United Nations (UN) Stockholm Conference. The conference, which took place with the participation of many countries in the process of development and industrialization, pointed out that the productive and healthy environment is the right of individuals. The conference is very important in terms of being the first conference to address the issue of environmental protection at the level of many different government officials. The conference emphasized that the measures to be taken for the protection of the environment should not be national but global. The Stockholm Declaration, consisting of 29 articles published at the end of the conference, laid the foundation for international environmental cooperation. In the Stockholm Declaration, although the term sustainable development was not used, emphasizing the importance of discussing environmental issues in international platforms has formed the basis of sustainable development (Bozloğan, 2005).

In the report titled ‘The Limits of Growth’ published by the Rome Club in 1972, it was emphasized that the relationship between environment and economy should be included in the development policies. In the report, it was questioned how much more natural resources on earth can be sustained compared to population growth and increasing consumption. Environmental pollution, hunger, poverty, lack of raw material resources, population growth, production-consumption imbalance were addressed and it was stated that these problems did not only threaten the future of certain regions, but also the future of the world. The report stated that increasing population and consumption would put pressure on natural resources. The report also clearly stated that if the population growth and consumption continue to increase rapidly, in the near future our planet will be based on the limits of growth and the world will not have the habitable quality. This report, also known as the ‘Zero Growth Report’, has been a sign of the need for sustainable development policies with the pessimistic approach of relationship among industrialization, environment and economy, although sustainable development was not covered as a concept (Yalçın, 2013).

The World Environment and Development Commission (WCED) was established in 1983 by the United Nations General Assembly to ensure that sustainable development is addressed within the legal framework. With the establishment of the World Commission on Environment and Development, it was emphasized that sustainable development can take place if a joint action is taken with the participation of many states. In 1987, the Commission published a report entitled ‘Our Common Future’. In 1987, Gro Harlem

Brundtland was the chairman of the commission. Therefore, this report is also known as the 'Brundtland Report'. The report highlighted four main points for sustainable development: reduction of poverty, future generations, basic needs, and resources. Brundtland report addressed many issues, from environmental problems to providing social peace, from energy sources to industrialization and urbanization, and from food resources to management policies and emphasized the importance of the continuity as much as the importance of development and production. In this report, the principles that sustainable development should include were presented.

The sustainable development process started with the Brundtland Report followed by the United Nations Conference on Environment and Development. The Conference on Environment and Development (UNCED) took place in Rio de Janeiro, Brazil on the 20th anniversary of the Stockholm Conference in 1992. The conference, which took place in June 1992 with the participation of thousands of people from 178 countries, is also known as the 'Earth Summit', 'World Summit', or 'Rio Conference'. The purpose of the conference is to evaluate the situation after the Stockholm Conference and to develop strategies for the solution of the problems related to development by acting jointly for the development-environment relationship. One of the most important features of the Rio Conference is to constitute more extensive sustainable development awareness by emphasizing that society has a very important place in the development process as well as the environment. At the conference, it was decided to organize economic policies and legal regulations in accordance with the principles of sustainable development and the existing principles and theories in theory were put into practice. The conference is important for bringing the sustainable development to the global level by presenting the opportunity to the governments that are the leaders of sustainable development in order to cooperate to solve the existing problems (Sahin, 2004; Uzun, 2007).

As a result of the Rio Conference, five documents were published under the names of the Rio Declaration, Forest Principles, the Convention on Biological Diversity, the Convention on Climate Change, and the Agenda 21. From these documents, the Rio Declaration provides a general framework for sustainable development and includes the duties and responsibilities of governments. In addition, the Rio Declaration is of great importance in terms of the fact that environment and human rights are highly related to each other, that environmental policies should not be separated from other policies, and that sustainable development will take place with the participation of societies (Bilgili, 2015). The Forest Principles are based on the principle of forest protection and reproduction. The Convention on Climate Change is based on the principle of conducting the duties and responsibilities of the States in cooperation in order to take measures to reduce the release of toxic gases that cause climate change. The Convention on Biological Diversity has been published for the protection of animal and plant species throughout the world. Agenda 21 is called as 'Agenda of 21st Century' because it aims to prevent the environmental problems in future generations while solving the problems of today's environment by examining the content of development and environmental strategies and the interaction between sub-chapters. Agenda 21 is an action plan for the achievement of sustainable development. The implementation of Agenda 21, which covers many national and international issues ranging from poverty to justice inequality, is the responsibility of states with the participation of individuals (Çamur & Vaizoğlu, 2007; Ökmen & Görmez, 2009).

Five years after the Rio Conference, the Rio+5 Summit was held in 1997 with the participation of 165 countries at the United Nations General Assembly. Rio+5 Summit, also known as the World Summit 2. The purpose of the gathering of the World Summit 2 was to assess the progress made in the name of sustainable development since the Rio Conference in 1992 until 1997 and to determine whether the decisions taken at the Rio Conference are implemented and how effective they were. In the World Summit 2 that aimed to determine whether the objectives of the Rio Conference were achieved and to determine the reasons for failure and the measures to be taken for the prevention, it was determined that the poverty and environmental problems continue in the less developed and developing countries, the advancement in the developed countries was limited, and the inequality between less developed and developed countries has increased. As a result of the conference, it was emphasized that the global recovery expected from the Rio Conference was not realized and that more concrete steps should be taken for the realization of sustainable development (Erdinç, 2016).

Another important initiative that needs to be addressed in the history of Sustainable Development is the United Nations Millennium Development Summit. The summit, also known as 'the Millennium Summit' or the 'Millennium Development Goals', was held in New York under the leadership of the Secretary-General of the United Nations Kofi Annan in 2000, with the participation of 189 countries. In the Millennium Summit largest summit held until that time, eight Millennium Development Goals (MDGs) that were planned to be successful in the local and global platforms until 2015 were determined. With the goals set at the summit, it was aimed to eliminate the problems and to ensure inter-governmental cooperation by ensuring that the development takes place on a global platform by emphasizing issues such as hunger, poverty, inequality of opportunity and environmental problems. The goals set as the Millennium Development Goals are a crucial step in terms of actualizing the main dimensions of sustainable development.

Another important step in the history of sustainable development is the United Nations Johannesburg Summit. The Johannesburg Summit, which took place 10 years after the Rio Conference in 2002, is also known as the Rio+10 summit. The Johannesburg Summit hosted 104 country leaders, private sector and non-governmental organizations. The purpose of the summit gathering is to determine to what extent the objectives and decisions related to the sustainable development determined in the Rio Conference were actualized in the 10-year period from the Rio Conference held in 1992 until 2002, and to work on eliminating the wrong arrangements and deficiencies. In the summit, many topics such as environmental protection, conservation of natural resources and economic use of them, fight against poverty, health, sustainable development, sustainable development for Africa, forming production and consumption strategies according to the principles of sustainable development have been examined. The Johannesburg Declaration and Johannesburg Implementation Plan were published at the end of the summit (Çımrın, 2014; UN, 2002; Arat, Türkeş, & Saner, 2002).

At the Johannesburg Conference, the participation of state leaders as well as private sector organizations and non-governmental organizations was very important to achieve the goals of sustainable development. In this conference, it was seen that specific and concrete steps were taken for sustainable development rather than abstract and general steps and projects and activities were carried out in cooperation of governments and organizations. The conference emphasized that sustainable development is a global responsibility (Bozlağan, 2010).

The United Nations Conference on Sustainable Development (Rio+20) was held in Rio de Janeiro, Brazil in 2012, 10 years from the Johannesburg Conference and 20 years after the Rio Conference (Tıraş, 2012). This was the largest meeting so far because it was held with the participation of forty-six thousand people. As in previous summits, the importance of sustainable development was emphasized in Rio+20 as well. In order to achieve the goals of sustainable development, a call for global cooperation has been made. At the conference, it was aimed to evaluate the decisions taken in previous summits, to fight against new problems, and to identify and eliminate the deficiencies (Özcan, 2016). With this conference, the commitment to the realization of sustainable development has been emphasized once again. At the end of the conference, a declaration of 53 pages and 283 items, called ‘The Future We Want’, was published. The 283 items in the declaration were prepared under the themes of our common vision, political stability, the green economy for the prevention of poverty in the context of sustainable development, the theoretical framework of sustainable development, the implementation framework of the sustainable development, and the methods of implementation. This declaration is a guide for the creation of the desired future (United Nations, 2012).

One of the activities organized in order to realize sustainable development is the UN Sustainable Development Summit held in New York in September 2015. The summit was held with the participation of 193 countries that are members of the United Nations. Although the Millennium Development Goals realized in 2000 had partial improvements, the Human Development Index data published in 2015 showed that this partial improvement was insufficient for sustainable development. After that, sustainable development targets for after 2015 were discussed and our Changing World: Sustainable Development 2030 Agenda was adopted. The global goals of the 2030 Agenda aims to compensate for the failure of the Millennium Development Goals. With the Agenda 2030, the global goals for sustainable development that are aimed to achieve success by 2030 are listed under 17 themes (United Nations, 2015; Şanlı & Armağan, 2017).

Conclusion

There is no other living space that human beings can live in except the Earth we live in. This shows that there is a high likelihood of future generations continuing to live in this world like people living on earth today. With the industrial revolution, the resources of our Earth have started to be consumed very quickly and the human population has started to increase rapidly as a result of the success of human beings with struggle against the nature. As a result of waste of resources, side effects of industrialization, and rapid population growth, our world has started to give signals of danger. Since the second half of the 1900s, this situation has been brought into the international agenda and many attempts have been made to take measures together. These developments have led to the emergence of the concept of sustainable development. The concept of sustainable development, which consists of the dimensions of Environment, Society and Economy, highlighted an approach to development that considers future generations. The understanding of sustainable development that especially the developed countries such as U.S. and China, which harms our world the most, continue to resist to implement is still the only way of survival for our planet and humanity.

References

Akgül, U. (2010). Sürdürülebilir kalkınma: Uygulamalı antropolojinin eylem alanı. *Ankara Üniversitesi Dil Ve Tarih Coğrafya Fakültesi Antropoli Dergisi, 24*, 133-164.

Akın, G. (2006). Küresel ısınma nedenleri ve sonuçları. *Ankara Üniversitesi Dil Ve Tarih-Coğrafya Fakültesi Dergisi, 46*(2), 29-43.

Alagöz, M. (2004). Sürdürülebilir kalkınmanın paradigması. *Sosyal Ekonomik Araştırmalar Dergisi, 1*(8), 1-23.

Alkan, A. (2015). Bitlis şehrinin çevre sorunları ve alınması gereken önlemler. *Doğu Coğrafya Dergisi, 21*(33), 11-36.

Alkış, S. (2007). Coğrafya eğitiminde yükselen paradigma: Sürdürülebilir bir dünya. *Marmara Coğrafya Dergisi, 15*, 55-64.

Altınışık, N. E. (2016). Modern İnsan Popülasyonlarında Arkaik İzler. *Kebikec: İnsan Bilimleri için Kaynak Araştırmalı Dergisi, (41)*, 283-294.

Altunbaş, D. (2003). Uluslar arası sürdürüebilir kalkınma ekseninde Türkiye'deki kurumsal değişimlere bir bakış. *Yönetim Bilimleri Dergisi, 1*(1-2), 103-118.

Altuntaş, A. (2012). Sürdürülebilir toplumlar ve metropollerin baskılarından kurtulmak için alternatif bir yol: Sürdürülebilir kentler. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 9*(17), 135-148.

Arat, G., Türkeş, M., & Saner, E. (2002). *Uluslar arası sözleşmeler ön rapor*. Vizyon2023; Bilim ve Teknoloji Stratejileri teknoloji Öngörü Projesi Çevre ve Sürdürülebilirlik Kalkınma Paneli.

Aslan, A. K. (2001). Eğitimin toplumsal temelleri. *Balıkesir Üniversitesi Sosyal Bilimler Dergisi, 5*, 16-30.

Aslan, F., & Çınar, R. (2015). Yeşil pazarlama faaliyetleri çerçevesinde kafkas üniversitesi öğrencilerinin çevreye duyarlı ürünleri kullanma eğilimlerini belirlemeye yönelik bir çalışma. *Kafkas Üniversitesi İktisadi Ve İdari Bilimler Fakültesi Dergisi, 6*(9), 1-16.

Atıl, A., Gülgün, B., & Yörük, İ. (2005). Sürdürülebilir kentler ve peyzaj mimarlığı. *Ege Üniversitesi Ziraat Fakültesi Dergisi, 42*(2), 215-226.

Aydoğan, A. (2010). *Sosyal bilgiler öğretmenlerinin sürdürülebilir kalkınma konusuyla ilgili kazanımların öğretimine ilişkin görüşleri*. Yüksek Lisans Tezi. Niğde Üniversitesi Sosyal Bilimler Enstitüsü İlköğretim Anabilim Dalı, Niğde.

Başol, K., Durman, M., & Çelik, M. Y. (2005). Kalkınma sürecinin lokomotifi: Doğal kaynaklar. *Muğla Üniversitesi Sosyal ve Beşeri Bilimler Araştırmaları Dergisi, 1*(14), 62-71.

Batı, O. (2013). *Türkiye'de sürdürülebilir kalkınma ve yenilenebilir enerji kaynakları*. Doktora Tezi. Marmara Üniversitesi Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, İstanbul.

Baykal, H., & Baykal, T. (2008). Küreselleşen dünyada çevre sorunları. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5*(9).

Bekiroğlu, O., & Balcı, Ş. (2014). Kültürler arası iletişim duyarlılığının izlerini aramak: İletişim fakültesi öğrencileri örneğinde bir araştırma. *Selçuk Üniversitesi Türkiyat Araştırmaları Dergisi, 1*(35), 429-459.

Bozlağan, R. (2010). Sürdürülebilir gelişme düşüncesinin tarihsel arka planı. *Sosyal Siyaset Konferansları Dergisi, 50*, 1011-1028.

Çamur, D., & Vaizoğlu, S.A. (2007). Çevreye ilişkin önemli toplantı ve belgeler. *TSK Koruyucu Hekimlik Bülteni, 6*(4), 297-306.

Çankır, B., Fındık, H., & Koçak, O. E. (2012). *Sürdürülebilirlik ve sürdürülebilir organizasyon yönetimi*. 1st International Conference On Sustainable Business And Transitions For Sustainable Development, Konya, 375-385.

Çetin, H. (2015). Sosyal adalet, sosyal hizmetler ve bütçe. *Journal of Society & Social Work, 26*(2), 145-157.

Çımrın, F. K. (2014). Kapitalizm, çevre ve çok uluslu şirketler. *Elektronik Sosyal Bilimler Dergisi, 13*(50), 175-187.

Çınar, E. G. (2017). *CBS tabanlı mekansal alanlar destek sistemiyle sürdürülebilir yerleşim alanlarının belirlenmesi*. Uzmanlık Tezi. İller Bankası Anonim Şirketi. https://www.ilbank.gov.tr/dosyalar/uzmanliktezleri/14706.pdf Erişim, 01.12.2017.

Çolak, C. (2012). İlköğretim-lise öğretmen ve öğrencilerinin sürdürülebilir kalkınma ile biyolojik çeşitliliğe ilişkin görüşleri. Yüksek Lisans Tezi. Karadeniz Teknik Üniversitesi Eğitim Bilimleri Enstitüsü Orta Öğretim Fen ve Matematik Alanları Eğitimi Anabilim Dalı, Trabzon.

Demirbaş, M., & Pektaş, H. M. (2009). İlköğretim öğrencilerinin çevre sorunu ile ilişkili temel kavramları gerçekleştirme düzeyleri. *Necatibey Eğitim Fakültesi Elektronik Fen Ve Matematik Eğitimi Dergisi, 3*(2), 195-211.

Dinç, A. (2015). *Bir sürdürülebilir kalkınma göstergesi olarak ekoloji ayak izi ve Türkiye*. Yüksek Lisans Tezi. Anadolu Üniversitesi Sosyal Bilimler Enstitüsü, Eskişehir.

Dücan, E., Polat, M. A., & Balcıoğlu, E. (2016). Tüketim toplumu olarak türkiye'nin cari açık ve tüketici kredileri ilişkisi. *Siyaset, Ekonomi ve Yönetim Araştırmaları Dergisi, 4*(1), 161-188.

Engin, H. (2010). *Coğrafya eğitiminde sürdürülebilir kalkınma, sürdürülebilirlik eğitimi ve çevre eğitimi konularının kazandırılması*. Yüksek Lisans Tezi. Marmara Üniversitesi Eğitim Bilimleri Enstitüsü, İstanbul.

Erdinç, B. (2016). *Avrupa birliğinde sürdürülebilir kentleşme: Türkiye'nin yansımaları*. Yüksek Lisans Tezi. Adnan Menderes Üniversitesi. Sosyal Bilimler Enstitüsü. Aydın.

Ergün, T., & Çobanoğlu, N. (2012). Sürdürülebilir kalkınma ve çevre etiği. *Ankara Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 3*(1), 97-123.

Eroğlu, K. (2004). Kadın kuruluşları içinde üniversite kadın sorunları araştırma ve uygulama merkezlerinin yeri ve önemi. *C.Ü. Hemşirelik Yüksek Okulu Dergisi, 8*(2), 23-31.

Eryılmaz, T. (2011). *Sürdürülebilir kalkınma kavramı ve Türkiye'de sürdürülebilir kalkınma*. Yüksek Lisans Tezi. Başkent Üniversitesi Avrupa Birliği ve Uluslar Arası ilişkiler Enstitüsü. Ankara.

Finding And Resolving The Root Causes Of The Sustainability Problem. http://www.thwink.org/sustain/glossary/ThreePillarsOfSustainability.htm (Erişim tarihi, 05.12.2017).

Giddings, B., Hopwood, B., & O' Brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. *Sustainable Development, 10*(4), 187-196.

Gürlük, S. (2010). Sürdürülebilir kalkınma gelişmekte olan ülkelerde uygulanabilir mi? *Eskişehir Osmangazi Üniversitesi İİBF Dergisi, 5*(2), 85-99.

Gürses, D (2009). 'İnsani gelişme' ve Türkiye. *Balikesir University Journal of Social Sciences Institute, 12*(21), 340-350.

Hayta, A. B. (2006). Çevre kirliliğinin önlenmesinde ailenin yeri ve önemi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD), 7*(2), 359-376.

Hayta, A. B. (2009). Sürdürülebilir tüketim davranışının kazandırılmasında tüketici eğitiminin rolü. *Ahi Evran Üniversitesi Eğitim Fakültesi Dergisi (KEFAD), 10*(3), 143-151.

Hopwood, B., Mellor, M., & O'Brien G. (2005). Sustainable development mapping different approaches. *Sustainable Development, 13*(1), 38-52.

Hürol, H. Y. (2014). *A study on social sustainability: The case of Doğanbey urban renewal project in Bursa*. Yüksek Lisans Tezi. Orta Doğu Teknik Üniversitesi, Mimarlık Bölümü, Ankara.

Kahriman, D. (2016). *Comparison of early childhood education educator's education for sustainable development practices across eco versus ordinary preschools*. Doktora Tezi. Ortadoğu Teknik Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.

Kara, B. (2017). *Akıllı bina cephelerinin sürdürülebilir kalkınma bağlamında incelenmesi*. Yüksek Lisans Tezi. Haliç Üniversitesi Fen Bilimleri Enstitüsü Mimarlık Anabilim Dalı; İstanbul.

Karabıçak, M., & Armağan, R. (2004). Çevre sorunlarının ortaya çıkış süreci, çevre yönetiminin temelleri ve ekonomik etkileri. *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 9*(2), 203-228.

Karakaş, B. (2015). *İç ve dış hava ortamlarında partiküler madde (pm10, pm2.5 ve pm1) konsantrasyonlarının değerlendirilmesi*. Yüksek Lisans Tezi. Hacettepe Üniversitesi Fen Bilimleri Enstitüsü, Ankara.

Kaya, E. (2013). *Sürdürülebilir kalkınma çerçevesinde Türkiye'nin nükleer enerjiye ilişkin politikalarının incelenmesi*. Yüksek Lisans Tezi. Karabük Üniversitesi Sosyal Bilimler Enstitüsü Kamu Yönetimi Anabilim Dalı.

Koçak, F., & Balcı, V. (2010). Doğada yapılan sportif etkinliklerde çevresel sürdürülebilirlik. *Ankara Üniversitesi Çevre Bilimleri Dergisi, 2*(2), 213-222.

Korkmaz, S. (2010). Türkiye'de ar-ge yatırımları ve ekonomik büyüme arasındaki ilişkinin var modeli ile analizi. *Journal of Yasar University, 20*(5), 3320-3330.

Korkmaz, M. K. (2015). *Yeşil tedarik zinciri yöntemi ve sürdürülebilir uygulamalar.* Gümüşhane Üniversitesi İktisadi ve İdari Bilimler Fakültesi IV. Ulusal Lojistik ve Tedarik Zinciri Kongresi Bildiriler Kitabı, 21-23 Mayıs. Gümüşhane: 1-13.

Kuşat, N. (2013). Yeşil sürdürülebilirlik için yeşil ekonomi: Avantaj ve dezavantajları türkiye incelemesi. *Journal of Yasar University, 29*(8), 4896-4916.

Levett, R. (1998). Sustainability indicators-integrating quality of life and environmental protection. *Journal of the Royal Statistical Society: Series A (Statistics in Society), 161*(3), 291-302.

Manzi, T., Lucas, K., Lloyd-Jones, T., & Allen, J. (2010). *Understanding social sustainability: Key concepts and developments in theory and practice*. Social Sustainability in Urban Areas. Communities, Connectivity And The Urban Fabric. London, 1-28.

Nergiz, N. (2011). Sosyal yardım ve sosyal hizmet açısından Isparta belediyesi: farkındalık, yararlanma ve değerlendirme açısından bir araştırma. *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 16*(2), 323-341.

Olsson, D., Gericke, N., & Chang Rundgren S. N. (2016). The effect of implementation of education for sustainable development in Swedish compulsory schools–assesing pupils's sustainability consciousness. *Environmental Education Research, 22*(2), 176-202.

Orman Genel Müdürlüğü, Ormanlarımız ve Faydaları. https://www.ogm.gov.tr/ekutuphane/Yayinlar/Orman%C4%B1n%20Faydalar%C4%B1.pdf (Erişim Tarihi, 10.12.2017).

Ökmen, M., & Görmez, K. (2009). *Türkiye'de yerel gündem 21 ve yerel yönetişim uygulamaları. Yerel yönetimlerin güncel sorunları*. Beta Yayını. İstanbul.

Özçağ, M., & Hotunoğlu, H. (2015). Kalkınma anlayışında yeni bir boyut: Yeşil ekonomi. *CBÜ Sosyal Bilimler Dergisi, 13*(2), 304-324.

Özçuhadar, T. (2007). *Sürdürülebilir çevre için enerji etkin tasarımının yaşam döngüsü sürecinde incelenmesi*. Yüksek Lisans Tezi. İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü. İstanbul.

Özdemir, Y., & Aras, M. (2015). Sosyal hizmetlerde kariyer yönetimi. *Süleyman Demirel Üniversitesi Vizyoner Dergisi*, 107-121.

Özerkmen, N. (2002). İnsan merkezli çevre anlayışından doğa merkezli çevre anlayışına. *Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi, 42*(1-2), 168-185.

Özkan, Ö. (2016). *Sürdürülebilir kalkınma ve Türkiye'deki çevre politikalarının belirlenmesi*. Yayınlanmış Yüksek Lisan Tezi. Marmara Üniversitesi Sosyal Bilimler Enstitüsü, İktisat Anabilim Dalı, İstanbul.

Özkan, K.B. (2017). *Sürdürülebilir kalkınma bağlamında çevre sorunlarının önemi: Türkiye ve AB karşılaştırması*. Yüksek Lisan Tezi. Bilecik Şeyh Edebali Üniversitesi Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, Bilecik.

Özmehmet, E. (2008). Dünyada ve Türkiye'de sürdürülebilir kalkınma yaklaşımları. *Journal of Yasar University, 3*(12), 1853-1876.

Özmete, E. (2010). Sosyal hizmette sürdürülebilir kalkınma anlayışı: Kavramsal analiz. *Sosyal Politika Çalışmaları Dergisi, 6*(22), 79-90.

Özsoy, F. N. (2015). *Sanayileşme olgusunun kirlilik sığınağı hipotezi ve çevresel vergiler açısından yeniden değerlendirilmesi*. Doktora Tezi. Gaziantep Üniversitesi Sosyal Bilimler Enstitüsü. Gaziantep.

Palabıyık, S., (2009). *Geleneksel ve yeni kalkınma kuramlarının analizi: Türkiye örneği*. Yüksek Lisans Tezi. Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü. İzmir.

Sandel, K., Öhman, J., & Östman, L. (2006). *Education for sustainable development: Nature, school and democracy*. Lund: Studentliterattur

Sarıçoban, K. (2011). *Türkiye'de uygulanan çevre politikalarının sürdürülebilir kalkınma üzerine etkileri*. Yüksek Lisans Tezi. Süleyman Demirel Üniversitesi Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, Isparta.

Sever, R. (2002). Sürdürülebilirlik bakımından şavşat ormanları. *Doğu Coğrafya Dergisi*, 77-97.

Sever, D. (2013). Science teacher candidates' thoughts about global warming studying in Turkey and United Kingdom. *Elementary Education Online, 12*(4), 1212-1221.

Şahin, Ü. (2004). Truva atı olarak sürdürülebilir kalkınma. Üç Ekoloji Dergisi, 2, 1-23.

Şahin, İ., & Kutlu, S. Z. (2014). Cittaslow: Sürdürülebilir kalkınma ekseninde bir değerlendirme. *Journal Of Tourism And Gastronomy Studies, 2*(1), 55-63.

Şanlı, İ. D., & Armağan, R. (2017). Sürdürülebilir kalkınma perspektifinden yenilenebilir enerji: Kamu politikalarının gerekliliği. *Süleyman Demirel Üniversitesi Vizyoner Dergisi, 8*(19), 93-109.

Tandoğan, D., & Özyurt, H. (2013). Bankacılık sektörünün ekonomik büyüme ve ekonomik kalkınma üzerine etkisi: Türkiye ekonomisi üzerine nedensellik testleri (1981-2009). *Marmara Üniversitesi İ.İ.B. Dergisi, 35*(2), 49-80.

Teksöz, G. (2014). Geçmişten ders almak: Sürdürülebilir kalkınma için eğitim. *Boğaziçi Üniversitesi Eğitim Dergisi, 31*(2), 74-97.

Tolunay, A., & Akyol, A. (2006). Kalkınma ve kırsal kalkınma: Temel kavramlar ve tanımlar. *Süleyman Demirel Üniversitesi Orman Fakültesi Dergisi, 2*, 116-127.

Toprak, D. (2006). Sürdürülebilir kalkınma çerçevesinde çevre politikaları ve mali araçlar. *Süleyman Demirel Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 2*(4), 146-169.

Tosunoğlu, B. T. (2014). Sürdürülebilir küresel refah göstergesi olarak ekolojik ayak izi. *Uluslar Arası Emek ve Toplum Dergisi, 3*(5), 132-149.

Tutar, F., & Yetişen, H. (2009). Türkiye'de kadının ekonomik kalkınmadaki rolü. *Niğde Üniversitesi İİBF Dergisi, 2*(2), 116-131.

Türer, B. (2010). *Fen bilgisi ve sosyal bilgiler öğretmen adaylarının sürdürülebilir kalkınma farkındalıklarının belirlenmesi*. Yüksek Lisans Tezi. Ondokuz Mayıs Üniversitesi, Eğitim Bilimleri Enstitüsü, İlköğretim Anabilim Dalı, Samsun.

Türkel, M. (2011). *Avrupa birliği ile müzakere sürecinde Türkiye'de sürdürülebilir kalkınma*. Yayınlanmış Yüksek Lisans Tezi. Ege Üniversitesi Sosyal Bilimler Enstitüsü Uluslar Arası ilişkiler Anabilim Dalı, İzmir.

Ulusoy, A., & Vural, T. (2001). Kentleşmenin sosyo ekonomik etkileri. *Belediye Dergisi, 7*(12), 8-14.

Uzun, N. (2007). *Orta öğretim öğrencilerinin çevreye yönelik bilgi ve tutumları üzerine bir çalışma*. DoktoraTezi. Hacettepe Üniversitesi Fen Bilimleri Enstitüsü. Ankara.

Uzun, N., & Sağlam, N. (2007). Orta öğretim öğrencilerinin çevreye yönelik bilgi ve tutumlarına 'çevre ve insan' dersi ile gönüllü çevre kuruluşlarının etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 33*(33), 210-218.

UNESCO. (2006). *United nations decade of education for sustainable development 2005-2014,UNESCO: International implementation scheme*. Paris.

United Nations. (1987). *Report of the world commission on environment and development: Our common future*. http://www.un-documents.net/our-common-future.pdf (Erişim tarihi, 02.12.2017).

United Nations. (2002). *Plan of implementation of the world summit on sustainable development*. http://www.un-documents.net/jburgpln.htm. (Erişim Tarihi, 02.12.2017).

United Nations. (2012). *Outcome document of the United Nations conference on sustainable development: The future we want. Rio de Janeiro*. http://www.un.org/disabilities/documents/rio20_outcome_document_complete.pdf (Erişim Tarihi, 03.12.2017).

United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (Erişim Tarihi: 03.12.2017).

Ünal, H., & Bağcı, E. (2017). Çevresel sürdürülebilirlik ve ekolojik ayak izi ışığında spor organizasyonları. *International Journal of Human Science, 14*(3), 3007-3021.

What İs Social Development? Economic And Social Inclusion Corporation. http://www2.gnb.ca/content/gnb/en/departments/esic/overview/content/what_is_social_development.html (Erişim Tarihi, 09.12.2017).

Yalçın, A., & Yalçın, S. (2013). Sürdürülebilir yerel kalkınma için cittaslow hareketi bir model olabilir mi? *Sosyal ve Beşeri Bilimler Dergisi, 5*(1), 32-41.

Yavuz, V. A. (2010). Sürdürülebilirlik kavramı ve işletmeler açısından sürdürülebilir üretim stratejileri. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 7*(14), 63-86.

Yeni, O. (2014). Sürdürülebilirlik ve sürdürülebilir kalkınma: Bir yazın taraması. *Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 16*(3), 181-208.

Yılmazer, M., & Onay, M. (2014). Bölgesel kuruluşların liderliğinde binyıl kalkınma hedeflerinin başarısı. *Ekonomi Bilimleri Dergisi, 6*(1), 1-16.

Yücel, F. (2003). Sürdürülebilir kalkınmanın sağlanmasında çevre korumanın ve ekonomik kalkınmanın karşıtlığı ve birlikteliği. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 11*(11), 100-120.

Yüksek, M. (2010). *Sürdürülebilir kalkınma ve Türkiye'de çevre politikaları*. Yüksek Lisans Tezi. Gaziantep Üniversitesi, Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, Gaziantep.

Zafir, Z. (1998). *Sürdürülebilir kalkınma ve az gelişmiş ülkeler*. Yayınlanmış Yüksek Lisans Tezi. Marmara Üniversitesi Sosyal Bilimler Enstitüsü İktisat Anabilim Dalı, İstanbul.

The Importance of Multiple Representations for Teaching and Learning Science

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Introduction

Science concepts are presented in multiple modes of representation such as text, diagrams, analogies, models, equations, mathematical relationships and computer simulations as well as different representations such as the macro, submicro and symbolic levels. A prime goal of teaching is to help learners develop an understanding of the science concepts under investigation by considering these different representational modes and levels. One way to understand how these different representational modes and levels help learners is to consider their functions as discussed in the theoretical framework of Ainsworth. In this chapter, I explain that without considering science concepts from the vantage point of several different representations, a full understanding of science may not be possible and learning opportunities are reduced. The chapter describes the findings in a case study of Year 11 students learning the human breathing mechanism with a range of different representations.

Modes of Representations

Students learning science are presented with a multitude of information in terms of text to read, words to listen to, experiments and activities, photographs, drawings, diagrams, models, charts, tables, equations, animations and simulations. These different modes of representation, used to depict scientific ideas, concepts or phenomena in a particular way, can be considered on a continuum from concreteness to abstraction – from doing experiments to using language to listen to ideas or to express them. Essentially, the purpose of these different modes of representing aspects of the same scientific ideas, concepts or phenomena is to help the learner develop his or her understanding of the scientific ideas, concepts or phenomena. However, there is significant research data to show that these expectations are not always met (van Someren, Reimann, Boshuizen, de Jong, 1998).

Levels of Representation

For the learner of science, there is an additional aspect to develop a complete understanding of a concept because each concept can be represented by different levels of abstraction. First used by Johnstone (1993) in chemistry education for explaining chemical events, these multilevel representations of concepts include the macro, the submicro and the symbolic. The macro level of chemistry such as the combustion of methane gas includes what one can see, smell or hear when doing the experiment.

How methane burns can be understood by knowing what happens at the submicro level, that is methane combines with oxygen to produce carbon dioxide and water. To have a deeper understanding one needs to know that a methane molecule is made of carbon and hydrogen and this can be represented at a symbolic level in a chemical equation: $CH_4 + 2O_2 \text{->} CO_2 + 2H_2O$. At the symbolic level, this chemical equation can be used to represent either the change in substances at the macro level or the particle interactions at the submico level.

In physics, there are similar levels of representation. The macro level refers to observable events such as the movement of a large box dragged across the floor or light reflecting from mirrors. For physics concepts, as for chemistry concepts, the submicro level is needed to develop an understanding of phenomena involved in understanding the gas laws. A deeper understanding of these events can be made using the symbolic level that can include arrows to show the forces acting, equations and graphing relationships; sometimes these relationships are of idealised phenomena such as not considering friction in a study of gas laws.

Biology has four levels in which concepts are represented because the organisation of biology knowledge is different to chemistry and physics. The macro level involves biological structures visible to the naked eye such as the plants and animals we see in our daily lives – making these observations was how the science of biology began. An additional level of representation in biology is the cellular where plant and animal cell structures invisible to the naked human eye are visible under a light microscope and sub-cellular structures visible under electron microscope. The submicro or molecular level involves DNA or proteins identified using analytical tools such as electrophoresis, chromatography, or a centrifuge. As with chemistry concepts and to a lesser extent physics concepts, the symbolic level provides explanations of phenomena such as metabolic pathways with chemical equations and numerical calculations or in the case of genetics representing inheritance patterns through genotypes or inheritance patterns, and for evolution using phylogenetic trees.

A Theory to Explain the Functions of Multiple Representations

As described by Opfermann, Schmeck and Fischer (2017), there a number of theories to best explain learning with multiple representations. One theoretical framework, that of Ainsworth (2006), describes the pedagogical functions of external representations in learning, namely to complement information and cognitive processes, to constrain interpretation/misinterpretation of phenomena, and to construct deeper understanding in problem solving and reasoning.

Many of the chapters in Tsui and Treagust (2013) used Ainsworth's framework, especially how information and processes from graphs, tables, equations, and pictures of scientific phenomena provide complementary information. For example, graphs allow patterns to be seen and equations indicate precise quantitative relationships of these patterns. Representations that constrain interpretation or misinterpretation of phenomena by familiarity or inherent properties can aid understanding when, for example, a diagram accompanying a description, by way of its inherent properties, can visually support the learners' interpretation of text that is not well understood. Lastly, different representations can promote the construction of deeper understanding through abstraction, extension, and relations.

Multiple Representations in Chemistry, Biology and Physics

During the past decade there has been an increased interest in research on teaching and learning science with multiple representations. Much of this research is in journals or chapters in books and not always readily accessible or easy to locate. An idea suggested to Springer was to bring much of the research on multiple representations for each of the science disciplines, chemistry, biology and physics, under separate covers. Springer accepted this idea and beginning with chemistry education research, John Gilbert and I invited authors researching in chemistry education and we edited Multiple representations in chemistry education. Some years later, Chi-Yan Tsui and I invited authors researching in biology education and we edited Multiple representations in biological education. More recently, Reinders Duit, Hans Fischer and I invited authors researching in physics education and we edited Multiple representations in physics education. Each chapter reports research about how multiple representations have been used to support and/or investigate student learning. Selected chapters from the three books, shown in Figures 1, 2 and 3, illustrate this range of topics with the multiple representations being in bold type.

Challenges

- Teaching structural representations in organic chemistry
- Better utilization of diagrams in research of learning chemistry
- Teaching chemistry with the symbolic level of representation

Improving existing pedagogy

- The role of practical work to emphasize the macro level
- Teaching inorganic qualitative analysis
- Linking macro and submicro levels with diagrams

Classroom Solutions

- **Structure-property relationships** involving meso levels in authentic tasks
- **Historical materials** - looking for explanations of macro phenomena
- The **role of multimedia** - computer simulations/animations

Figure 1. Selected Chapters with Emphasis on Different Multiple Representations in Chemistry Education (Gilbert & Treagust 2009)

The role of multiple external representations in learning biology

- **Pictures** in biology education
- Possible **constraints of visualisation** in biology
- Learning **genetics reasoning** with multiple representations
- Learning and biotechnological methods with **animations**

Implications for biology teaching and teacher education

- Multiple representations in **human genetics** in textbooks
- Understanding **photosynthesis and cellular respiration**
- Representation and decoding of **complex process diagrams**
- Learning **tree diagram thinking** in evolutionary related taxa

Assessment of learning and teaching with multiple representations

- The development of **systems thinking** in biology education
- Secondary students' understanding of **genetics using BioLogica**
- **Analogy and gesture** for mental visualisation of DNA structure

Figure 2. Selected Chapters with Emphasis on Different Multiple Representations in Biology Education (Treagust & Tsui, 2013)

Focus on models and analogies

- Teaching and learning representations in upper secondary physics
- Integrating **computational artifacts** into multi-representational toolkit
- Evaluating multiple **analogical representations**

Focus on multiple modes

- **Social semiotics** in university physics education
- Learning optics with multiple representations
- Enacting a representation construction for **astronomy**
- Learning about **forces** using representations
- Textbooks' representations of **electric current**

Focus on reasoning and representational competence

- Representational competence in **geometrical optics**
- Effective **use of representations** in physics learning
- Role of representations in **dynamics, thermal physics**
- **Global heat transfer** in an online learning environment

Figure 3. Selected Chapters with Emphasis on Different Multiple Representations in Physics Education (Treagust, Duit & Fischer, 2017)

Learning Science with multiple representations

Research from these three volumes and other publications (for example, Eilam & Poyas, 2010) has shown that effective use of different modes and multiple representations can

- improve students' understanding of science conceptual knowledge
- enhance students' problem-solving skills
- reduce difficulties in understanding the links between different representations
- lead to less fragmented knowledge and more coherent understanding and
- increase students' enjoyment of learning science.

When students do not master the ideas within the different representational modes and levels, their learning opportunities are reduced. For example, when students do not recognise the reasons for using a ball and stick or space filling models to explain particular molecular phenomena, they misunderstand the reason for using these different models in learning. Similarly, they do not connect the macro level laboratory work to explanations of observed chemical phenomena at the submicro level and represent chemical reactions with symbols. Indeed, the goal of teaching should be to move mentally between the three levels of representations with a high level of understanding why this is taking palace. It is also likely that not fully understanding the different representational modes and levels can lead to the development of alternative conceptions (Adadan, 2013; Kohl & Finkelstein, 2017).

Science teachers frequently make well-meaning assumptions about students' ability to use and understand the different modes and representations and how they function. However, when students have difficulties understanding and integrating different modes and levels of representation, this can give rise to ineffective learning. One way to address this situation is to overtly emphasize the functions of these different representations. Faced with several representation of the same concept, students with a limited understanding tend to focus on surface features of a representation to prevent being overloaded with information (Sweller, 2005). Often students prefer to use only one or two representations. This situation was demonstrated in the work by Kuo et al. (2017) when first year university non-major physics students were taught optics phenomena with representations of descriptions of the phenomena using words, drawings, equations and graphs; they tended to refer to only two representations in tasks despite being asked to use words, drawings, equations and graphs.

Learning the human respiratory system with multiple representations

As noted above, multiple presentations are ubiquitous in science and how the teacher and his or her students attend to the different representations in their learning can have vastly different outcomes. I illustrate these different outcomes by referring to a study conducted by Won, Yoon and Treagust (2014) that examined the roles of representations contributing to students' conceptual understanding of the human respiratory system.

The research took place in a Year 11 Human Biology class taught by an experienced biology teacher at a private girl's school in Australia. Students in Year 11, the penultimate year of secondary school, are 16-17 years old. The lessons on the topic of the human respiratory system took place over four class hours, during which time the teacher taught the subtopic of the human breathing mechanism using the different representations of a bell-jar model-which is a simple analogical model for the lungs and human thorax, textbook diagrams, written text and verbal explanations.

In addition to the classroom observations, the researchers interviewed students in pairs, audio recorded and transcribed the interviews, and compared and checked all data. The authors used a deductive-inductive data mining approach to identify students' learning strategies and understanding of the underlying concepts. Students also completed items on the breathing mechanism from a two-tier diagnostic test previously developed by Mann and Treagust (1988). An example of a diagnostic test item is shown in Figure 4.

Each lung is a large hollow sack that is like a balloon that expands and contracts to get air into and out of the lung

- A. True   B. False

The reason for my answer is:

- There is a model that shows the lungs as two balloons in a cavity. The balloons expand to let air into them and get smaller to push air out of them.
- The lungs are composed of lots of little sacks and the air entering them makes them expand.
- The lungs are made up of a lot of tiny sacks and the lungs expand and contract as the thoracic (chest) cavity changes its volume.
- The lungs are two hollow bags and their volume changes because the diaphragm pushes and pulls on them.
- Other reason

Figure 4. Diagnostic Test Item on the Human Breathing Mechanism from Mann and Treagust (1988)

In this research, we adapted Ainsworth's framework to analyse the pedagogical functions of different representations used by students to explain their understanding of the human respiratory system, namely, to determine how different representations complemented information and cognitive processes, or constrained the interpretation/

misinterpretation of phenomena, or evaluated their learning showing a deeper understanding and reasoning.

In the research paper by Won et al. (2014), three distinct ways were identified in which students used four multiple representations (model, diagram, text, and verbal explanation) to build their concept of the human breathing mechanism. One group of students showed a critical understanding of the nature of each of the representations and developed a coherent, scientific explanation. In such cases, the model of the bell-jar and the lung diagram in the textbook were used by students in a complementary manner, representing different aspects of a concept. Further, students with this level of understanding were able to recognise the limitations of the model in relation to the explanation in the textbook.

Another group of students developed mostly correct explanations but had an incomplete understanding of the different representations. These students were able to explain the concept using one representation but they demonstrated some minor problems in interpreting another representation (the lung diagram) or in transferring their interpretation of one representation (the bell-jar model) for another (the lung diagram). Students with this understanding, the verbal text constrained their interpretation of the model.

A third group of students searched for a one-to-one correspondence between one representation (the bell-jar model) and another (the lung diagram), resulting in incorrect explanations. While understanding the analogous nature of the bell-jar model, they did so without critical evaluating the different representations and did not consider the limitations of the model or the differences between the two representations. Further in the diagnostic test, they displayed naïve conceptions that their teacher in his oral presentation to the whole class explicitly described and warned them about.

This study provided clear evidence about the different approaches that students used to interpret multiple representations for learning about the human breathing mechanism. An analysis of these different approaches can be used by teachers and students to help learning outcomes with multiple representations.

Summary

Multiple representations are ubiquitous in science education teaching and learning. For example, science textbooks often show more than one representation on a single page. A textbook having text adjacent to one or more representations as photographs, drawings, diagrams, models, charts, tables, or equations is common, almost the norm. The reader needs to be able to make sense and analyse why, say, a paragraph about increased heart rate during exercise also has a heart rate - time graph and a picture of a track athlete. The graph can provide information complementary to the text and provide deeper understanding of the concept or it could constrain the meaning of the text. The photograph of the athlete is likely to provide the context and/or is intended to be motivational. To learn science concepts with these different representations, students need to analyse them in order to make judgements about their utility in helping make scientific explanations. To increase students' interest in science, teachers and curriculum specialists provide experiments or demonstrations as well animations and simulations. In every case, without appreciating the vantage point of the different representations, a full understanding of science may not be possible and learning opportunities may be reduced.

References

Adadan, E. (2013). Using multiple representations to promote grade 11 students' scientific understanding of the particle theory of matter. *Research in Science Education, 43*(3), 1079-1105.

Ainsworth, S. E. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16,* 183-198.

Eilam, B. & Poyas, Y. (2010). External visual representations in science learning: The case of relations among system components. *International Journal of Science Education, 32*(17), 2335-2366.

Gilbert, J. K. & Treagust, D. F. (Eds.). (2009). *Multiple representations in chemical education*. Springer.

Johnstone, A. H. (1993). The development of chemistry teaching. *Journal of Chemical Education, 70*(9), 701-704.

Kohl, P. B. & Finkelstein, N. (2017). Understanding and promoting effective use of representations in physics learning. In Treagust, D. F., Duit, R. & Fischer, H E. (Eds.). *Multiple representation in physics education* (pp. 231-254). Springer.

Mann, M., &Treagust, D. F. (1998). A pencil and paper instrument to diagnose students' conceptions of breathing, gas exchange and respiration. *Australian Science Teachers' Journal, 44*(2), 55-59.

Opfermann, Schmeck and Fischer (2017). Multiple representations in physics and science education – why should we use them? In Treagust, D. F., Duit, R. & Fischer, H E. (Eds.). *Multiple representation in physics education* (pp. 1-22). Springer.

Treagust, D, F &, Tsui, C-Y. (Eds.). (2013). *Multiple representations in biological education*. Springer.

Treagust, D. F., Duit, R. & Fischer, H E. (Eds.). (2017). *Multiple representation in physics education*. Springer.

Van Someren, M. W., Reimann, P., Boshuizen, H.P.A., de Jong, T. (Eds.). (1998). *Learning with multiple representations*. Amsterdam: Elsevier.

Won, M., Yoon H. & Treagust, D. F. (2014). Students' learning strategies with multiple representations: Explanations of the human breathing mechanism. *Science Education, 98*(5) 840–866.

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