Education Research Highlights in Mathematics, Science and Technology 2017

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Section 1: Mathematics Education

CONVERSATION AS A SPACE FOR STUDENTS' LEARNING IN MATHEMATICS CLASS: RE-VISIONING COMMUNICATIVE INTERACTIONS

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ABSTRACT: The importance of communication for the learning of mathematics is well established in mathematics education literature. The context of the reported inquiry looked beyond cognition in mathematics class related to specific content to explore how students could develop learning processes to improve their approach to high school mathematics. Conversation, as a specialized construct of communication, holds promise to inform how teachers and students could attend to growth in learning processes and selves in the context of mathematics class. The curriculum inquiry first identified key studies from mathematics education which use conversation as context for students' mathematical learning. Philosophical approaches that underpinned the studies were examined, such as hermeneutics, narrative, dialogism, care, epistemological frames, and enactivism. The philosophical traditions contained assumptions and conceptualizations of conversation which provided theoretical potency for this type of communicative act in mathematics class. The results of synthesis of the philosophical traditions indicates that conversation can be an effective space for high school mathematics students in engaging in learning to learn mathematics given consideration for five key features, learning and growth as aim, and the relational space of conversations.

Keywords: conversation, mathematics education, curriculum inquiry, learning to learn

INTRODUCTION

Communication has been identified as a crucial process within mathematics classrooms. Mathematics educators have invested significant energy into researching various aspects of mathematical communication (Choronaki, & Christiansen, 2005; Elliott & Kenney, 1996), including communicating through writing (Masingila & Prus-Wisniowska, 1996; Author1; Morgan, 1998; Pugalee, 2004), effective instructional strategies for increased student understanding (Nathan & Knuth, 2003), and one-on-one and whole class communication (Bills, 2000; Gresalfi, Martin, Hand, & Greeno, 2009; Pimm, 1984). The range of methodologies in researching communication in mathematics classrooms rivals the various foci, such as discourse analysis (Truxaw & DeFranco, 2008; Zolkower & Shreyar, 2007), action research (Herbel-Eisenmann & Cirillo, 2009; Raymond & Leinenbach, 2000), hermeneutics (Davis, 1996; Gordon Calvert, 2001), and semiotics (Radford, 2003).

While most studies focus on talk about mathematical content, what seems to be subordinated to the mathematics is the educational moment embedded in the communication. A kind of dialogue which attends to the educational moment – a *conversation* – among a teacher and her/his students cultivates a different kind of learning experience. *Conversation* allows a teacher to attend to students – as students, learners, individuals, and relational persons – and to be present with them in the classroom. *Conversation* enables students to make sense of the mathematics they are learning and the ways in which they go about learning mathematics. In other words, *conversation* provides space and time to not only inquire into mathematics, but to inquire into students' learning processes.

In high school mathematics class, students are often advised to do more practice questions or study harder in order to get better grades. These platitudes leave many frustrated and with declining achievement. Rather, students with their teachers can work on adapting these platitudes to develop personalized learning strategies which support them in actively making connections among mathematical ideas so that the skills they practice are meaningful. Attention is given to how students go about learning mathematics—the learning processes they use—to improve their approaches. Students require opportunities to work and talk with peers and with their teacher to create and refine learning processes, where *conversation* supports students in learning (how) to learn mathematics. *Conversation* provides opportunities for teachers and learners together to (re)form their identities, their relationships among each other, their approaches to learning mathematics, and their relationship with mathematics.

This significant shift in communication in the mathematics classroom has prompted a re-examination of literature, both of research in mathematics education and the locations in which the mathematics educators have grounded their notions of *conversation* in the broader endeavor of curriculum inquiry. C*onversation* can be viewed in at least two different manners: as a way of inquiring into curricular issues and as the phenomenon being explored.

However, as *conversation* is not the only label that educational researchers use to name a specific communicative act, I included *dialogue*, *discussion*, and *discourse* as forms of communication in mathematics class.

Interpreting the author's meaning of terms related to conversation in literature was challenging. Occasionally, it became clear that the author would use a word in a colloquial manner, where the meaning was simply that there was some form of communication and terms could be exchanged without change the author's claim. As well, communication among individuals does not necessarily need to be restricted to an oral/aural mode, but also a written interaction between individuals.

In this article, I represent a search for understanding what it means to be in conversation as a way to sponsor rich learning of mathematics and self situated within a mathematics classroom. This search was a journey along paths that had already been laid down (Varela, 1987) by others by surveying related literature in mathematics education and curriculum inquiry. The landscape metaphor encapsulates well the process of beginning with mathematics educational researchers and then moving along their pathways toward the source pathways that contributed to their journey. The exploration of source pathways highlighted topographical features, for instance paths crossing over each other (direct referencing to each other) or paths being laid down in parallel (attending to similar ideas, in different contexts or described in different metaphors). Within the landscape, the pathways did not converge on one destination, but dispersed across the landscape of communication. The discussion of the curriculum inquiry and mathematics education literature will point to a coherence of the uses of *conversation* in the literature, suggesting how the notion of *conversation* provides a rich space for further exploration of how teachers and students might focus on learning in mathematics classrooms

Mathematics Educational Researchers' Perspectives on "Conversation"

Several mathematics educators have shaped the landscape of communication within mathematics education. In addition to pragmatic issues, they have returned to philosophical notions within curriculum inquiry as a way to be aware of and understand the qualities of communication in mathematics classrooms. In turn, they contribute to a broader, philosophical understand of *conversation* that supports further research by mathematics educators. The representation of the heads of the pathways, in an essay structure, takes on a linear form even though traversing the landscape included moving from path to path freely.

Davis' (1996) earlier work focused on the act of listening in classrooms, and how conversations enacted through listening provided profound opportunities for a teacher to view teaching as conversing. He applies the notion of *hermeneutic conversation* in his inquiry into the teaching of mathematics. Davis makes a clear distinction between *conversation* and *dialogue* in hermeneutic inquiry, where *conversation* is seen as the site in which a hermeneutic inquiry occurs and *dialogue* marks the communication. It is within the site of conversation that a fusion of horizons can occur. As well, he describes a distinction between *discussion*, where there is a goal of imposition of perspectives on others, and *conversation* as "less oriented to point out differences and more concerned with arriving at shared understandings" (p. 39). In emphasizing *conversation*, Davis also remarks that while preparation is essential and fluidity is fundamental, there is a recognition that a conversation can only be realized retrospectively, "when self and other have been altered" (p. 28). For Davis, the aim of conversation is ontological growth and creation of knowledge.

Ernest (1993, 1998) has explored the use of *conversation* as a metaphoric understanding of learning within mathematics, especially within a social constructivist framing. Epistemologically, Ernest (1998) traces the educative notion of *conversation* back to the ancient Greeks through philosophers that view the dialogic interaction as one that forms the foundation of the growth of mathematical knowledge. He uses *conversation*, *dialogue*, and *dialect* interchangeably, yet focuses on the primacy of *conversation* in learning mathematics. Ernest (1993) sees *conversation* about mathematics as an interpersonal endeavor that includes:

- Mutual respect and trust between teacher and learner;
- Listening to learners; showing (and feeling) an interest in their views, in their conceptions, and in their sense-making;
- Making teaching into *real* conversation … where there is space for learner initiative too;
- Treating real subjects and content of mutual interest and of mutual benefit. (p. 7)

Although Ernest's notions of *conversation* are grounded in epistemological stances, he ascribes to *conversation* as a moral form, where rather than "exchanging information ... it entails engaging with a speaker or listener as another human being" (p. 7). Within Noddings' (1984) and Ernest's (1993) writing, the notion of the dialectical emerges.

Their uses of *dialect* seem to point to *discussion* of content that is highly valued (moral actions for Noddings and mathematical concepts for Ernest).

Within mathematics education, attending to epistemological stances of students typically means exploring how students construct knowledge of specific mathematical concepts. The focus is on the mathematical content with minimal awareness of the complexity of the learner. However, Cobb and his colleagues (Cobb & Bauersfeld, 1995; Cobb, Boufi, McClain & Whitenack, 1997; Sfard, Nesher, Streefland, Cobb & Mason, 1998) attend to both the mathematical knowledge being constructed and the quality of the learning experiences for learners in mathematics class. *Discourse* points to the forms and languaging (both verbal and symbolic) used within the community of the mathematics classroom. Cobb et al. (1997) describe *collective reflection* as important in learning about mathematical objects and is "supported and enabled by participation in the discourse" (p. 264). Here, communication is to not only be located intimately between teacher and learner, but within the context of the whole class.

Although Cobb's interest lies in *discourse* as a meta-communicative structure, he views *conversation* as a process in which learners need to engage in order to learn deeply. As well, *discussion* is used as a generic term for talk exchanges in the classroom. Cobb (in Sfard et al., 1998) suggests that research studies need to be located in classrooms to understand the nature of effective conversations. Further, Bauersfeld (1995) makes strong claims that communicating in mathematics class has an "impact on personal development" (p. 272) and "the totality of everyday experiences forms the basis for the personal development, interactively, and in all dimensions of the sense" (p. 283). Situated within communicative acts, there are openings for learners to learn about learning within the process of growth.

Gordon Calvert (2001) explored a discourse of conversation, rather than viewing conversation solely as a way to improve mathematical cognition. She defined a mathematical conversation as "something where both persons, together, were trying to come to an understanding of some mathematical phenomenon." (p. 5) Here, *conversation* is seen in a relation between two individuals (there is an intimacy implied) where the focus is on understanding, rather than the mathematical phenomenon itself. *Conversation* emerges and flows in ambiguity around topics valued by all participants, in the interpersonal interaction marked by listening through an opening up of self to be responsive and ethically responsible to others, and toward understanding both the topic and the personal experiences of all participants. Gordon Calvert provides a cautionary note: that conversations, as embodied processes, cannot simply be understood through an attending only to text or words, but to lived experiences of those who enact conversations within a culturally and historically active environment.

After studying pairs of people in conversation around mathematical inquiry tasks, Gordon Calvert (2001) concluded her book by pointing to some features of mathematical conversation. The first feature, *gestural genre*, refers to "interactive gestures – verbal, physical, pictorial, and symbolic" (p. 133) that support communication. The second feature, *addressivity toward the other*, refers to an intimacy of attending to the conversational partner with a person's whole self. The third feature, *addressivity toward otherness*, refers to attending to the relationship between the conversation partners and the mathematics that coemerges between them. The world that is brought forth in conversations, as Gordon Calvert identifies, is contingent on the coemergence of understanding each participant's experiences within the particular context.

"Conversation" Pathways in Curriculum Inquiry Literature

Progressing along each of the pathways that began with an inspection of particular mathematics educators' uses of communicative terms directs this exploration toward the pathways the mathematics educators have travelled as they explored communicative acts in their research. Each of the studies cited above were grounded in particular philosophical traditions that shaped their use of communicative terms. This next section travels the pathways of the philosophical traditions employed within curriculum inquiry to note how they have informed mathematics education and how they might be re-read to support an exploration of *conversation* for growth in mathematics class. It is useful to explore this literature as curriculum inquiry provides the lens through which studies in mathematics curricular issues are carried out.

Etymology

Before exploring the literature, I examined the etymology of *conversation* and the other three terms. According to Oxford Etymological Dictionary (Hoad, 1986), the salient historical constructions of the words are:

> *Conversation* – Latin *conversātiō*; Old French *converser* (p. 96)

(mode of) living, dwell, dwelling habitually
familiar discourse
exchange words
acquaintance, company, associate familiarly *with*
turn round

Dialogue – Old French *dialoge*; Latin *dialogus*; Greek *diálogos* (p. 123)
conversation, discourse
dia-: through, apart (Greek) (p. 123)
-logue: speaking or treating of (Greek *-logos*) (p. 270)
logos is account, ratio, reason, argument, discourse

Discussion – Latin *discutere* (p. 127)
investigate
examine by argument
dash to pieces

Discourse – Latin *discursus* (p. 127)
reasoning
conversation, talk
running to and fro
argument
di-: twice, two (Latin or Greek) (pp. 123 & 126)
-currere: run

Analyzing the etymology of these four words provides some interesting commonalities and distinctions to which we can attend. *Conversation* is the only one of the four that does not have "argument" as a historical connection, but instead includes a relational, intimate stance in the communication as the individuals are familiar with each other, with the connotation of living together.

As well, *conversation*, *dialogue*, and *discourse* form a triad. On one hand *discourse* is a meta- term for conversation (in that a conversation is seen as a particular kind of "familiar" discourse). On the other hand, *conversation* is referred to by both discourse and dialogue. In terms of language and cultural origins, all words have Latin roots, although *dialogue* is unique in its Greek roots. This could mean that *conversation* and *dialogue* were to point to the same phenomenon but arose in different cultures.

Finally, *conversation* is the only word that includes the idea of "turn round," which I see as connoting a turning round of ideas in the talk, rather than a moving back and forth between ideas in the "running to and fro" of *discourse*. This could be understood as an intertwining of ideas (and individuals, in the intimacy) in *conversation*, while ideas are held up against each other in *discourse*.

Hermeneutics and Hermeneutic-phenomenology

Hermeneutics and hermeneutic-phenomenology are two closely laid paths informing curriculum inquiry. Davis, Ernest, and Gordon Calvert have identified these paths as crucial in their understanding of *conversation*. Moving between these two paths seems inevitable, especially in the work of Gadamer (1965/1975) and van Manen (1997) who have both merged the two paths together. The exploration of *conversation* in hermeneutics and hermeneutic-phenomenology is not surprising because of the "persistent questioning of our taken-for-granted-modes of speaking and acting" (Davis, 1996, p. 26) and Jardine's (1992) view that hermeneutics "returns inquiry to the need and possibility of true conversation" (p. 124). In this context, the use of *conversation* is used to point to the engagement of curriculum inquirers in deep and thoughtful understanding of educative experiences for children – an inquiry stance.

Gadamer (1965/1975) highlights the use of *conversation* over other forms of communicative acts. He uses *dialogue* as a counter-example, where truths are constructed through the use of logical arguments or to generally point to communication between two people. *Conversation* is framed by Gadamer (1965/1975) as a careful consideration of other's understandings, focused by the topic under consideration, structured through question and answer (or testing), "ensure[s] that the other person is with us" (p. 331), does not have a fixed destination, and primarily occurs between text and an interpreter. In explaining conversation between two individuals, Gadamer recognizes letter writing as a form of written conversation:

To understand what a person says is, as we saw, to agree about the object, not to get inside another person and relive his experiences. We emphasised that the experience of meaning which takes place in understanding always includes application. (p. 345)

The intimate nature within the etymology of *conversation* is taken up by Gadamer.

Van Manen's (1986) description of the pedagogical relationship makes tangible this intimacy in noticing the growth of a child, where many of his vignettes highlight spoken interactions between child and teacher. van Manen (1977) uses the language "interpersonal communication" (p. 213) as the core of Schwab's (1969) *practical* approach to curriculum development, "a conversational relation" (p. 111) as the basis of putting words to the pedagogic experience, and *discourse* as a overarching concept for forms of speech.

Narrative Inquiry

Narrative inquiry supports researchers in noticing the experiences of teachers and learners in mathematics classrooms. My previous research demonstrates the strength of *conversation* as way of being with students in a classroom and as a method of data collection (Author2). For Clandinin and Connelly, "narrative is the best way of representing and understanding experience" (2000, p. 18) and for Bruner (1986) narrative is a mode of thinking, which means that humans think narratively about their experiences, as they both tell and come to understand their experiences. Clandinin and Connelly (2000) use *conversation* primarily as a form of data construction within a narrative inquiry. *Conversation* is used in place of "interviews" because they are "marked by equality among participants and by flexibility" (p. 109) and act as "a probe into experience that takes the representation far beyond what is possible in an interview … done in a situation of mutual trust, listening, and caring for the experience described by the other." (p. 109) In this way, the use of *conversation* highlights the relational qualities of narrative inquiry (Connelly & Clandinin, 1990).

Moving back to the paths laid down by some of the scholars whom Clandinin and Connelly relied on in shaping narrative inquiry provides some insight into the use of the communicative words in this exploration. Bruner (1986) focuses on the use of *discourse* as a particular form that is comprised of the features of "presupposition", "subjectification", and "multiple perspectives" (pp. 25-26). He also juxtaposes arguments with stories in what and how they convince individuals. Sarris (1993) uses *conversation* to refer to "talking back and forth" (p. 4) and as a general taking up of *dialogue*. Geertz, as described by Clandinin and Connelly (2000), uses *discourse* to refer to a broader system of talk that signifies particularities of authorship.

Taking up narrative inquiry, Florio-Ruane (1991) found that *conversations* needed to be "open and extended" (p. 240), characterized by camaraderie, critical to the research, and moved naturally toward story-telling. She noticed that when the author and audience are close to one another there is a rich common contextual knowledge, so the text is "*exophoric* in reference" (p. 247) – contextual references for the meaning of what is said resides outside of the text. Texts which are *endophoric* in reference mark a distance between author and audience – contextual references for the meaning of what is said resides within of the text. Perhaps *exophoric* writing is indicative of the intimacy of *conversation*, where meaning cannot be drawn only from the single verbal interaction but needs to occur within the whole of the individuals' relationship and shared experiences

Dialogic Reality

Ernest's philosophical exploration of conversation explores a dialogic pathway, emerging from the works of Bakhtin and Vygotsky. Bakhtin saw *dialogue* as a way of being in the world, "as central for defining human existence, not merely a form of communication. To experience what it means to be human, one needs to engage in dialogical relations. We are human in the fullest sense when we engage in dialogue" (Sidorkin, 1999, p. 4). Because living in dialogue is the way in which a person shapes her or his own self, as well as showing her or his identity to others, there is a significance for learning by engaging learners in dialogue. Bakhtin characterizes *dialogue* as an aim for life itself where it places a person in relation with another with no defining cause, and *conversation* as a mode of communication (Sidorkin, 1999).

Shotter (1995) extends Bakhtin's dialogic reality toward *conversation*. Although at times he uses *conversation* and *dialogue* interchangeably, it seems that when individuals are in conversation, they are "*responsively* linked in some way" (p. 52, emphasis in the original). As he continues, he describes this connection as "ethically or morally interlinked with others" (p. 54) that is borne out in a sense of responsibility to the other. His primary contribution to the understanding of *conversation* is that it is a joint action, where it is not only the individuals that shape the conversation but the words and the objects that emerge within the conversation (they do not exist before the conversation) act to shape the conversation itself and the identities of the participants.

Gee (1996) extends Vygotsky's interconnection of thought and language, emphasizing the importance of the social interactions in learning through discourse communities. He describes movement from Vygotsky's *spontaneous* *concepts* (students learn but "have no conscious reflective awareness of or control over" (p. 275)) to *nonspontaneous concepts* (there is a conscious control) as calling for a "working collaboratively with others who 'know' more than one does *and* (simultaneously) via overt instruction that focuses on putting things into words, conscious and intentional use of the new concepts, and the relationships among forms and meanings" (p. 275, emphasis in the original). This includes talk about new concepts through the collaboration, viewed in this context as *discourse*.

Care as a Moral Stance

The shaping of a moral education, through mathematics education, has been a pathway that mathematics educators like Ernest and I have explored. While my earlier research with at-risk grade 10 mathematics students (Author2, Author3) has been shaped by Noddings' (1984) ethic of care, Ernest highlights *conversation* as a moral way of being with others. His stance has tremendous synchrony with Noddings' work. For Noddings, "ethics" is understood as the study of morality, of how individuals meet each other morally, and she views a relation that is caring as the basis of ethical action in that "we recognize human encounter and affective response as a basic fact of human existence" (p. 4). With the relational, and encountering each other with care as basic to this philosophical stance, it is useful to attend to how individuals ideally interact through speech within a caring relation. Noddings focuses on the use of *dialogue* as one of the central aspects in moral education for "nurturing the ethical ideal" (p. 121). As in her ethic of care, relationships are central to *dialogue* and this form of interaction is marked by being open, genuine, sharing, seeking the best of the other, and reflecting. In the classroom, a teacher and learners would engage in "talking and listening, sharing and responding to each other" (p. 186), where learners are encouraged to think out loud in initiating and trying out ideas, while the teacher listens intensely and then directs. Additionally, Noddings uses *discussion* to point to an open exploration of how individuals have acted and how they could act in moral and ethical ways.

Meier (1995) took Noddings' ethic of care and moral education with her as she developed an alternative public-school program in Harlem grounded in the philosophy of caring. *Conversation* is used predominately in Meier's book, *The Power of Their Ideas*, as demonstrates the significant learning which students engaged in as their voices were valued in their schooling. Although Meier does not define or characterize her use of *conversation* explicitly, observations she shares provide the audience with a sense of how conversations were taken up in her school. There is an openness where ideas flow in the midst that provides opportunities for students' voices to emerge (through their valuation) and be heard, where voices build on each other in the development of ideas, and conversation is held within a relationship of mutuality. Additionally, Romano (2000) uses *dialogue* to represent interactions where the teacher listens intensely with the aim of understanding learners, attending to them in multiple ways, and where the learners feel a sense of respect and openness where all are included and valued. She views *dialogue* as a crucial aspect in forming an educative community within a classroom.

Epistemological Frameworks

Another region in the landscape of communication that could inform an understanding of *conversation* are paths of epistemological models. Both Ernest and Cobb (and his colleagues) have traversed this area of the landscape in developing their understandings around *conversation*. Noddings (1984) noted that caring is rooted in a feminine ethic, which has lead to considering two epistemological frames that consider gender as informative in epistemological stances. In Belenky et al.'s (1986) frame, the ways in which women interact in order to come to know is highlighted within connected knowing. Connected knowing seeks to build knowledge from personal experience, and connecting relationally with others is important in coming to understand their personal experiences for the creation of knowledge. These scholars tend to favour *conversation* over other forms of communication, because they view mutuality, drawing on personal experiences to connect to one another, listening carefully, cooperation, openings for emergent ideas, and equality of individuals within the talk. They juxtapose *conversation* with *discourse*, which they view as a "masculine adversary style" (p. 221) and as something done *to* another and not *with* another. In contrast, Baxter Magolda (1992) predominantly uses *dialogue* to point toward meeting others relationally in the classroom, where there is an openness and a responsiveness to individuals' experiences as being educative.

While these epistemological frames address learning academic content generally, there is a shift toward positioning with learning as a space for growth. Huber with Whelan (2000) position *conversation* as "a vital way of knowing" (p. 123), where individuals are interconnected as they enter the conversation in mutuality. As well, Huber and Whelan point to the richness of data constructed through conversations. In exploring their tendency toward *conversation*, over *discussion* or *dialogue*, Godard et al. (1994) describe the informal, participatory, fluid, and interdependent nature of *conversation*. Three interesting contributions are made through their writing: first, the relational intimacy described through the word "betweenness" (p. 120); second, using "collective conversation" to refer to group interactions; and third, their sense that *conversation* refers to an oral/aural space and *dialogue* refers to a textual space of communication. They understand *discourse* to represent a meta- term for all forms of communication.

Clark's (2001) study of teacher learning is situated within *authentic conversations* where "social and intellectual work is done" (p. 6), and occurring both in oral/aural spaces and through letter writing. Clark views learning and growth as occurring with the context of conversations, when *conversation* is thought of as centred on topics that are valued, participation is voluntary yet marked by active engagement, developed over time within trusting and caring relationships where individuals can be personally invested, and aim to understand experience through improvised explorations. He also defines *dialogue* as a particular form of conversation directed at "new understanding, where the participants question, analyze, and critique the topic or experiences" (p. 160).

Enactivism

As a final pathway in this exploration, a theory of cognition key for many mathematics educators is enactivism. In particular, Davis and Gordon Calvert have used enactivism as a framing to come to understand educative experiences within mathematics. Conceptualized and explicated by Maturana, Varela, and their colleagues (Maturana, 1988; Maturana & Varela, 1988; Thompson, 1987; Varela, Thompson, & Rosch, 1991), enactivism turns to biological roots to describe cognition as embodied. This embodiment highlights that "knowledge depends on being in a world that is inseparable from our bodies, our language, and our social history" (Varela, Thompson, & Rosch, 1991, p. 149) and that "knower and known, mind and world, stand in relation to each other through mutual specification" (p. 150). In other words, there is a coemergence of knowledge among individuals in the bringing forth of a reality in the moments of interaction. This stance lead Gordon Calvert (2001) to shape a *conversarial reality*, emphasizing that "humans exist in conversation" (p. 39) and that our experiences occur within conversations as well as our coming to understand our experiences.

A forum at a meeting of the *International Conference of the Psychology of Mathematics Education* explored enactivism within mathematics education. Among the four papers presented and discussed, only *discussion* and *dialogue* appeared in one text to point toward phenomena under study in classrooms. Even in relative silence about communicative acts, each of the papers identified a key understanding from enactivism: that teachers and students are shaped by their environments and how they interact in their environments, and at the same time the environment is shaped by how the teachers and students act on it. Coles (in Brown, Coles, Lozano, & Reid, 2009) describes his interest in "the role of whole class discussion (particularly the teacher's role) in the development of [mathematics classroom] cultures and individual learning" (p. 1-19). He emphasizes the importance of looking for patterns in coming to understand "classroom dialogue" (p. 1-19), especially without forming *a priori* categorizations.

Making Sense of the Literature on Conversations

I have re-presented a broad range of understandings of *conversation* by scholars who have laid down paths within and outside the field of mathematics education. Traversing each of the paths, I attended to the use of *conversation*, *dialogue*, *discussion*, and *discourse* by noting which word is primarily used by the scholars, describing how they have used this word to point conceptually to the particularities of communication, and using the other words to make distinctions.

As I mapped out these paths, I considered the features of these paths and how they might illuminate and inform the shift in *conversation* from focusing on mathematical cognition to focusing on attending to students as they learn (how) to learn mathematics while engaging in the dynamic process of (re)forming their identity. While the other three terms related to communicative acts can be used in some context, *conversation* emerges as a label that points to the type of communicative act that supports a careful and thoughtful attention to learning and to reformation of identity. What follows in this section is a synthesis of the effective elements of *conversation* drawn from the literature represented above.

Etymology

Etymologically, *conversation* can effectively point to how teachers can attend to students and open up space to explore learning processes in mathematics classroom. Two significant aspects that are particular to *conversation* are the relational intimacy and the turning round. A relational orientation to teaching and exploring learning processes is essential because the explorations are deeply personal and contribute to (re)formation of identity. To become more effective at specific learning processes, turning the processes round within conversations provides opportunities for students to shape the processes and for the teacher to support and scaffold the refinement.

Philosophical Understanding

The (existential) philosophical question of how humans are in this world, the fundamental question of the nature of existence could be addressed through the notion of *conversation*. Coming to understand living within an authentic conversation space could uncover a different way for a teacher and learners to exist in a classroom, so that their experiences lead toward rich learning. The teacher, in conversation with learners, would have opportunities to learn how to invite and engage learners in conversations about their learning, learn more about how her or his learners are learning in mathematics class, and learn how to live with learners in a classroom differently than is the current dominant practice (for instance, the teacher's learning significantly affecting assessment and evaluation practice in the classroom so much so that it changes the nature of the relationship and existence of the teacher). The learners, in conversation with their teacher, would learn more about how they each learn mathematics in particular ways, learn how to shape existing or construct new effective learning strategies, and learn how to exist in empowering ways with their teacher (for instance, the co-inquiry of teacher and learners contributing to a less hierarchical existence).

Five Features of Conversation

In addition to working at a foundational level of coming to understand *conversation* through its etymology and philosophical underpinnings, attending to features which characterize *conversation* is important in sponsoring and noticing conversations in classrooms. Various features arose for me, as a I travelled the paths other scholars had laid down, that spanned across the paths and seemed to contribute significantly to the shaping of the use of *conversation*. In defining or demonstrating what a *conversation* is, scholars relied on detailed, and often extensive, lists of features to support their and their audience's sense making of their use of the concept. I drew out five features that I view as critical to conversations in classrooms that could support learning about learning and growth of the conversational participants.

The first feature, that of collaboration or *withness*. Within a setting where the interpersonal is valued, relationships are formed through an ethic of care. Living within these relationships, individuals meet each other ethically as they mutually negotiate a sense of trust and equality where they feel both safe to talk with others and responsible to be responsive as they nurture the relationship through their interactions. The (inter)connection entails a notion of intimacy that provides space for individuals to learn in collaboration. The sense of *withness* helps create the conversational space and is also strengthened through the conversations that occur within that space.

Taken up within *withness* is a second conversational feature of *listening*. Quite often, explorations of *conversation* focus on what the speaker is contributing, but the non-speaker(s) is/are active participants throughout as they engage in authentic listening in preparation to respond. The act of listening is integral to the conversational space, being present and responsive to the other. It is within the listening stance that all participants can come to a significant understanding of themselves, others, and the object of the conversation. Listening could mean that the teacher does not position herself/himself as an expert in students' learning, but rather a mutual inquiry that attends closely to how learners talk about their learning to prompt, encourage, guide, and respectfully challenge to sponsor richer and deeper understandings of learning. The learners themselves would also engage in listening by maintaining a sense of openness to learning about their learning, supporting other learners in their learning journey (by being in conversation with them and shaping learning strategies together), and by attending to their emergent understandings of learning to see how it is affecting their learning.

While it is important to understand how the conversational participants are relating to each other within the conversational space, their conversations could also be characterized as being *dynamic* (as a third feature). The dynamic nature of conversations could relate to at least two aspects, the topic that is under consideration as well as the flow of the conversation. *Dynamic* could be a particularly useful way to think about conversations because it contains both the idea of being in constant change or flux, and also being energetic or productive. In the first sense, there is a certain fluidity in the course of an authentic conversation, where rather than the participants being in control of the turn-taking and the movement of the topic(s), the mutuality and relatedness of the participants provides space for the conversation to coemerge. There is a notion of fluidity, flexibility, and anticipation of the unexpected within the conversational space.

In the second sense, there is an investment in the conversation by all the participants – an understanding that personal change and growth can occur by their active participation. This investment is sponsored by the focus (topic) of the conversation, that it is something of mutual interest or concern to all participants and participants have a strong sense of its value for their own growth. This focus is something that often emerges within the conversation, rather than being directed at the outset. The *dynamic* feature could be central to a teacher and learners' co-inquiry into how students learn – that ways of learning are co-constructed and subsequently shaped as the conversation flows among the participants and that active engagement talking about how to learn mathematics effectively can be valued by a teacher and her/his learners.

Extending from the fluidity that occurs within the conversation, a fourth feature of a conversation is the *uncertainty* of where the conversation leads participants and how the conversation is understood afterwards. Because the conversation and the focus emerge among the participants, there is no sense of (a predetermined) destination at the outset, nor is there a sense of what specific elements would be achieved at the end of a conversation. The hermeneutic conversation holds the notion of shared understandings as the direction toward which a conversation leads.

There is a tension between the uncertainty that exists in an authentic conversation about learning processes and sharing with students effective learning processes with the expectation that they make use of them. It might help in this context to consider the uncertainty being enacted through series of conversations about learning processes that there is no way to ascertain or fix in what ways and how teachers and learners might grow through ongoing conversations. The *exophoric* notion of conversation extends from the features of *withness*, *dynamic*, and *uncertainty*. This is clearly drawn from social orientations to learning, and supports the notion that rich learning needs to be situated in a conversational space. An *exophoric* orientation to interpreting a conversation highlights the necessity of a researcher to be imbedded in the research context.

The fifth feature of conversations is the additional form of conversation, aside from oral/aural, contained with *written* pieces. This article begins with this as a premise, but it is also brought forward in several of the pathways. Within a classroom space, it is unrealistic to expect a teacher to regularly have oral/aural conversations with each learner one-on-one about her/his learning within the flow of classroom activities, no matter how intentional the teacher is and how much he/she values that conversation. The process of interactive writing provides space for intimate conversations to occur between a teacher and each of her or his learners, a space that is safe for learners to share their emergent thoughts about their learning and a space where a teacher can scaffold learning about learning in specific and effective ways for each particular learner

Purpose of Conversations

Two purposes of engaging individuals arises along two trajectories: learning and growth. Learning seems to be related to an epistemological stance, while growth seems to be related to an ontological stance of positive movement and development. While the purposes of learning and growth are not mutually exclusive within a classroom, there were some scholars that explored learning (Cobb et al., Ernest, Gordon Calvert), others that explored growth (Bauersfeld, Huber & Whelan) or both (Clark, Davis). Interestingly, the scholars who focused on learning as a purpose of engaging learners in conversation highlighted the effects that conversations have on the quality of learning mathematics. Their concern was within a domain-specific cognitive experience. The set of scholars who focused on growth as a purpose of engaging learners in conversation were interested in how conversations could support the ontological growth of individuals, attending to who they were becoming as it related to their shifts in identity and in relation to others. Clark and Davis, who were intentional about both purposes, noticed that conversations were effective in improving and strengthening practices (teacher and mathematical) that were represented by both learning and growth.

Through inviting and engaging students in conversations about learning processes, learning and growth are tightly intertwined because the learning that a teacher and learners engage in is about each of their selves, how they learn, and how they learn about learning. Rather than focusing on the learning of a subject area content, although contextualized within mathematics, the learning is about self – looking inward at how one learns as an individual, how one positions oneself with coming to know and knowledge (epistemological stance), and how one is being and becoming through the (re)formation of one's identity (ontological stance) and looking outward at how one learns in collaboration with others.

Space of Conversations

Learning and growth, interrelated purposes of engaging in conversation, could occur in at least two different conversational locations. Within a classroom, there are patterns, forms, and languaging that I see creating a *discourse* space. These three aspects of the *discourse* are negotiated between a teacher and learners. In addition to mathematical discourse, there could also be a learning discourse that is shaped. The learning discourse is the location where a teacher and learners actively engage in talking about learning and learning processes with the goal of increasing their awareness of learning and become more effective learners.

Two possible spaces for conversations include those that occur between a teacher and a learner, one-on-one, and conversations that occur among a teacher and a class of learners. The nature and form of a conversation will differ somewhat between these two spaces. The one-on-one conversations are intimate exchanges because there are only two conversational partners that are interacting quite personally and specifically, within the learning needs and goals of the particular learner and at the same time also contributing to the shaping of the pedagogic relationship. These conversations between teacher and learner extends from talk as a whole class about learning, and exists and develops over time. So, in order to distinguish the one-on-one conversations between teacher and learner, they could be labelled as *intimate conversations*.

There is a difference sense of the conversations which occur within a class setting, among a teacher and her or his learners. The talk within the broader discourse space could be seen as a *collective conversation* in the sense that many are involved in the shaping of the community and the learning of the community. The adjective points to the intention of collaboration within the whole community. The space of conversations grows out of a relational orientation, where relationships among conversational participants are negotiated and fostered.

CONCLUSION

The re-investigation of how communicative acts are taken up in mathematics education has been offered in order to imagine an alternative, and potent, possibility for engaging in conversations in mathematics classrooms. Much research has focused on how students communicate mathematically—about the mathematics and in support of reasoning mathematically. But the necessity of attending to the experiences of students in mathematics classrooms calls for the focus and intentions of *conversation* in mathematics classrooms to struggle with what it means for students to learn how to learn mathematics, to develop effective learning processes, and to be ontologically shaped by their experiences in mathematics class.

Conversation takes up a sense of *withness* and *listening* in a *dynamic* process and with a *uncertainty* in destination and understanding that provides opportunities for mathematics educational researchers to explore the essential experiences of learners of mathematics. Acknowledging that students' experiences in mathematics class affect more than their cognition is not sufficient. In order to support the success of *all* students in mathematics classes, coming to understand the qualities of effective conversations for supporting learning (how) to learn mathematics and reformation of identity is necessary. I invite others to engage in the challenges of shaping conversations about learning in mathematics class.

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HIGH LEVEL CONSTRAINTS WEIGHTING ON THE POSSIBLE SHAPES KNOWLEDGE CAN TAKE ON

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ABSTRACT: In this paper, we present a study that can be seen as a partial bridge between didactic researches centered around epistemological concerns like epistemological obstacles and sociological approaches that can be used in educational sciences. To do so we use an anthropological approach to the didactic of mathematics, the anthropological theory of the didactic (ATD) and in particular its "scale of levels of didactic codetermination". This enables us to bring into the fore a set of constraints emanating from institutions located at a high level of this scale. The two institutions we are considering are the modern mathematics reform and the counter-reform that followed. The constraints generated by these institutions form a dense network that compels the possible shapes mathematical knowledge can take on. Such stringency leads to some hybridization of the deductive and argumentative architecture of courses subdued to these constraints. The concepts become two sided. They bear at the same time a mathematical side, the most visible one, which has a mathematical legitimacy and another less visible one whose role is to allow these concepts' ecological viability. The implicit and unconscious shifts between these two polarities tend to reinforce cultural mimetic encounters of knowledge based on ostensive practices.

Keywords: ATD, epistemology, anthropology, mathematics, economy, constraints

INTRODUCTION

This paper presents an ongoing research. It is short since we formally began to work on this topic only two months ago. Moreover, we are not yet able to fully position ourselves among the existing literature because of the specific context in which this research emerged. It first began as a teacher questioning and not a researcher interrogation: "How is it that in spite of all our efforts, the failure rates to our course is so high?" From this initial teacher perspective, an answer had to be found, not in scientific papers, but by merely "looking" at our high school's ordinary working.

Nevertheless, the study of this question led us to gradually depart from our initial approach in two ways.

- We had to consider a new question, related to the initial one, about high failure rates: the question of understanding antinomies found within our own course. This new question became the central one, the other being subordinated to it.
- We were "forced" to embrace theoretical tools that would allow us to tackle this new question, namely the *Anthropological Theory of the Didactic* (ATD) developed by Yves Chevallard (1992). Most notably we will make use of one of its fundamental tools, the *scale of levels of didactic codetermination*. ATD had indeed the potentiality to endow us with concepts allowing us to formulate hypotheses about the possible shape a mathematical knowledge can take on.

These two elements mark our transition from teachers to researchers.

This paper is structured as follow. We start by giving an account of the salient steps that took us from our initial question of high failure rates, to a scientific approach and the question of antinomies. We then give an example of an antinomy to illustrate what we mean by it and at what level it is located. The section that follows introduces ATD and the tools we need to interpret these antinomies, namely that they are the resultant of two opposing types of institutional constraints. We conclude with the importance of taking into account those types of constraints, if one wants to be able to understand what shape a knowledge can or cannot take on in a mathematical course.

FROM A TEACHER QUESTION TO A RESEARCHER QUESTION

Let us start by first explaining the institutional framework in which our initial question took place. We and three other teachers are giving a mathematical course to 500 first year students in a Belgian high-school in economy, business and management. The course content is very similar to a secondary school curriculum. There is a chapter devoted to the "theory" of functions which limit itself to real function of a single real variable, assorted with a few concepts, those found in secondary school, like, for instance, domain of a function, injectivity and monotonicity. Then, coming chapters devoted to specific classes of functions (first degree functions, second degree functions, etc.). Among these chapters, one is of special interest for our purpose. We will draw on it to give an example of what we call antinomies within the course. This chapter deals with exponential, logarithmic and reciprocal functions. Another chapter deals with non-constrained optimization, of one real variable functions, using derivatives (study of the first and second derivatives). Those reminders are broadened out with classical economic applications: budget line, elasticity, and equilibrium between supply and demand.

Besides these secondary level chapters, they are two others dealing with topics new to students. One chapter is introducing *elements* of first order logic, mostly logical connectors ($\wedge$, $\vee$, $\neg$, $\Rightarrow$) and quantifiers ($\exists$, $\forall$). Another is introducing linear programming restricted to two variables. These linear programming problems are not solved by the simplex method, but rather using a geometrical approach that consists in calculating an "intersection" between a polygon and a parallel sheaf of lines.

One reason for the limited course content is the great variety of students' profiles. Some didn't do any mathematics for one year or more, while others had 8 hours of mathematics per week. Among these varied profiles, none seems to be more prevalent than others.

The only salient fact we had to face are the high failure rates, between 50% and 75% for the last five years, despite numerous attempts to improve the situation: new exercises with detailed solutions, improved explanation based on reocurring errors, decreased number of students in groups, methodology courses part of the curriculum, etc. Our purpose is not to detail all the innovations devised by teachers but rather to highlight the amount of energy invested and the almost zero return, to the point some of our colleagues didn't want to be in charge of the course anymore.

Different leads were envisioned to explain the situation. Might the problem be related to the new knowledge (logic and linear programming)? This hypothesis turned out to be false. Students had as much trouble with secondary school knowledge than with linear programming. Might the high failures rates be correlated with the number of hours per week students had in secondary school? The answer was negative as well. More hours didn't mean higher success rates. Given those negative answers, a trend among our colleagues emerged: the students themselves had to be the reason for the high failure rates: they are not working enough and they show no real interest in mathematics.

This standpoint cannot be entirely rejected, for it is true that our students are rather immature. For instance, when given (very easy) exercises to prepare, most don't do anything, except wait for the teacher to give the "right" answer. In classroom, they spend more time playing with electronic devices than working on mathematics. The list of immature behavior is almost endless but it is not our point to be harsh on the students and blame them for everything. Even if we share the idea that they should be more involved in their studies, we were led to take into consideration another dimension that remained hidden for quite some time.

We found antinomies within our own course. We thus had to consider the possibility that these were, at least partly, accountable for students' high failure rates. We moreover thought this lead was all the more credible for several reasons. They were many of them, not just a few. They were scattered throughout the course and they were all related to the course's deductive architecture. That could not be a coincidence.

ANTINOMIES

Let us give an example of an antinomy found in the chapter introducing exponential functions and logarithmic functions as reciprocal of exponentials. We first start by pointing out "strange things" within the chapter then we explain why these "strange things" together form an antinomy.

A first problem is found, right from the start, within the very definitions of these types of functions. The exponential functions are defined as functions of the form:

$$x \mapsto f(x) = C \cdot a^x$$

where $C \neq 0$, $a > 0$ and $a \neq 1$. The problem is that this definition does not satisfy the property:

$$f(x + y) = f(x) \cdot f(y)$$

later announced as a fundamental property of exponentials. Put that way, the contradiction seems blatant. How did it get unnoticed? The way it is dressed in the course is rather tricky and not that easy to detect. The initial definition given to students is that of functions having an exponential growth ($x \mapsto f(x) = C \cdot a^x$). At that point in the course it is not clear if these functions are meant to be exactly the exponential functions or not. It is only by looking carefully at various semantic shifts that we finally have to conclude that functions having an exponential growth are the same as exponentials functions. Without that careful analysis, the problematic connection would have gone undetected.

We now turn to the second definition, that of logarithmic functions. Contrary to the chapter's purpose, they are not explicitly defined as reciprocal of exponentials, but instead, in a rather loose way, using notations that allows students not to integrate this relationship and its relevance:

$$\exp_a(x) = y \iff x = \log_a(y)$$

The reciprocal relationship between exponentials and logarithmic functions is merely stated afterwards, as a property among many others. This leads us to another oddity.

All exponentials and logarithmic functions' properties are on an equal footing. The fact that some are consequences of others is completely silenced. This leveling resonates with the given "proofs" of those properties.

They are no actual proofs of exponential functions' properties. In place, we find formal plays between the notations a^x and $\exp_a(x)$, used to "reformulate" the various properties. The status of these plays is never clarified to the students to the point that some do consider them as genuine proofs.

Getting back again to logarithmic functions, we find this time actual proofs but no unified proof principle is put forward. Each proof is a special case requiring some form of "illumination" on the part of the creator. The reciprocal operator on functions is not presented as a mean to automatically transport properties from one class of functions to another. The reciprocal operator thus plays no role in the deductive architecture of logarithmic functions, not even in its definition. What is then its purpose in the course?

The above description of the chapter about exponentials and logarithmic functions exemplifies what we label as an antinomy. It is the global way exponentials and logarithmic functions are treated that is antinomic. Looking from a distance, we might be under the illusion that a perfectly ordinary deductive presentation of the subject is given to students. But, exerting a sharper look, reveals "strange details" that, taken as a whole, highlight an evanescent deductive architecture. This is where the antinomy is located: the presence of a deductive architecture looking at the big picture and no deductive architecture looking closer.

This example, characteristic of antinomies found in the course, rises questions. Here are a few, given in no particular order, to illustrate the dynamic antinomies are able to generate.

- (Q1) How is it possible for such an elementary course to be filled with antinomies?
- (Q2) Why are our colleagues left rather unmoved or at best annoyed when we present them with these antinomies?
- (Q3) Why did it take us so much time to detect these antinomies and be able to put them into words?
- (Q4) Why maintain the illusion of a deductive architecture when there is almost none? To what end?

Answers to these questions, formulated as hypothesis, can be given when we introduce the theoretical tools of the next section.

THEORITICAL FRAMEWORK

What kind of theory do we need to address questions 1 to 4? Because of their specific nature, the studied antinomies are not that easy to detect or talk about. They are not, so to speak, "direct" mathematical errors, like an erroneous proof, or a computational mistake. They nevertheless belong to the mathematical sphere. They are related to the relationships teachers have towards mathematics, relationships that end up in a double play around the course's deductive architecture. Based on this characteristic, we felt we had to turn ourselves towards a didactical theory that could take into account the relationships people can have with knowledge. This is precisely some of the things

ATD[1] is capable of. A basic tenet of ATD is to consider knowledge as emerging from human practices (Chevallard, 1992). These practices happen in institutions. In ATD's sense an institution can be an institution in an ordinary sense but it is not limited to that. It can be, for instance, a particular school of thought, like bourbakism we shall talk about in the next section. The strength of this approach is to take a step back from epistemologies, like Platonism, that consider knowledge, especially mathematical one, as something immutable, independent of any cultural background, at least when its "true essence" has been put to light. Taking that step back allows oneself to formulate hypothesis about antinomies or any didactical problem in terms of institutional disparities. This is what ATD calls *analysis of transposition* (Chevallard, 1991). Such an analysis has been a main tool of action in the French school of didactics, for several decades. This is the theoretical framework which we adopt in this paper.

The analysis of transposition is somewhat formalized relying on the *scale of levels of didactic codetermination* tool (Chevallard, 2005). The basic idea leading to the scale is to take into account the impact on knowledge of institutions located at different strata of society, ranging from a specific mathematical subject, like the definition of exponential functions, to civilization issues. Taking into account all these strata can be seen as a tangible mark of ATD's willingness to be a systemic approach to didactic. An institution located at the level of civilization is for instance the peculiar way Greek mathematicians envisioned numbers. To them, the only genuine ones were the natural numbers. Without taking this relationship to numbers into account, it is hardly possible to understand Greek Mathematics.

The strata are arranged into a scale. The levels of that scale, from the lowest to the highest, are: subject, theme, sector, domain, discipline, pedagogy, school, society, civilization. The sequencing used in the scale is just a convenient way or organizing the strata and, by no mean, implies any kind of superiority of the high levels of the scale upon the low levels. The low to high sequencing merely captures the idea of taking into account institutions having broader and broader scopes.

According to Schneider (2013), the scale of levels is, among other things, what reveals ATD's scientific potential, because the crossing of different levels allows one to put to test the hypothesis drawn from ATD about a specific issue, antinomies in our case. Those hypotheses are thus falsifiable in the sense of Popper (1959). This turns the "specific issue", together with the hypothesis put forward within ATD's framework, into a didactical phenomenon and not just an opinion. We will use the word *phenomenotechnical* to qualify ATD's scientific potential as elaborated by Schneider (2013) who built on Bachelard's neologism phenomenotechnical found in his famous applied rationalism (1949).

INSTITUTIONAL CONSTRAINTS

Armed with the spirit of ATD, we now consider two institutions located at high levels of the scale (society and above). The first one is the modern mathematics reform and the second one the counter-reform to the modern one.

Institution I: the modern mathematics reform

Starting in the 30s, Bourbaki, a group of mathematicians, deeply changed mathematics. They helped to unify it relying on structures, spreading to the whole discipline, what van der Waerden (1930) had begun in algebra. The benefits were considerable and still have repercussions nowadays. They helped to pave the way to previously unsolved problems: Fermat's last theorem not to mention it. One key feature of structures is the ability to use a way of tackling a problem in a particular context and to transfer it to another that are governed by the same structure (Houzel, 2004). This initiative comes at a cost. Since then mathematics are based on more abstract concepts than ever before (Aczel, 2009). With Bourbaki, structures, the axiomatic method of Hilbert and deductive architectures have more than ever become part of what mathematics are.

This revolution led, together with other factors (economical, political, intellectual), to reform secondary school curricula, starting in the sixties (Houdebine, 1994). The modern mathematics reform was born. One strong trend found among the teaching principles was that abstract structures have to be taught from the start because they were considered to be "natural" for they are "isomorphic" to "structures" found in human minds (Charlot, 1984).

Abstract group theory (Dienes, 1971) and set theory (Papy, 1963) are taught in secondary school and even in primary school in some cases.

[1] It is a complex theory with lots of concepts. We shall limit our presentation to those that fit our needs. The interested reader will find a detailed account of ATD in, for instance, Bosch & Gascon (2014).

The reform turned out to be a global disaster. Pupils could at best understand mathematics as a (meaningless) game based on (mathematical) words, they saw no connection to the “real” world (Houdebine, 1994).

Institution II: the counter-reform

By the end of the 70s, the modern mathematics reform was put to sleep. A counter-reform took place that intended to undo the damages of the reform. This broadly meant: make mathematics meaningful (again). The perceived collusion between Bourbaki’s unifying effort and the reform led the counter-reform to somewhat go against what mathematics had turned into the 20th century. Set « theory » including notations were put aside as it was seen as one of the most meaningless aspect of the reform. Structures were also mostly put aside. The only remains were pieces of the theory of functions. Those pieces are the ones still present nowadays in secondary school we alluded to in the previous sections: injectivity, reciprocal, etc. The deductive architecture of mathematics, including proofs, became less important than the following principles.

- Mathematical concepts should be strongly linked to the « real » world
- Teaching should proceed from « concrete » to « abstract »
- Learning activities should be centered on pupils’ background…

Putting it all together

We might be as much critical about the reform than the counter-reform. It is not our point here. Instead our goal is to explain how the articulation between these institutions allows us to make sense of the antinomies discussed in the previous sections.

In Belgium, to become a mathematics teacher, you first need to have a degree in mathematics[2] (5 years) and then you are trained to become a teacher during 1 year. So, a teacher foundation is first of all that of a non-professional mathematician: you learn about theories but you are not supposed to actually engage in any kind of research. The kind of mathematics they learned are mostly highly formalized following mathematics’ evolution impacted by Bourbaki among others. So, to them, mathematics is all about structures, deductive architecture and proofs. This is what you mostly learn in courses: theorems and their proofs. Most teachers do not therefore consider the possibility of doing genuine (that is rigorous) mathematics another way.

But the counter-reform puts them in a paradox. How do they teach mathematics, “as they are”, if their essence is frowned upon? They have to embrace nowadays students, the children of the counter-reform, and the somewhat contradictory constraints from institutions I and II. One way of dealing with such a situation is to use concepts that resemble their genuine mathematical counterparts. Those pedagogic concepts are “designed” for their ability to be given a “concrete” meaning.

For example, the reciprocal of a function’s role, in the course, is not to transfer properties from exponentials to logarithmic functions. Such a use of reciprocals is deemed too “abstract” from the counter-reform point of view. The teachers thus have to resort to tricks to conciliate both institutions they are subordinated to. On the one hand, they have to make use of reciprocals because that is a sound mathematical way to proceed from the first institution’s perspective. On the other hand, they have to ornament the reciprocals’ mathematical use to fit it into the counter-reform ideology and the resulting school ecology. So, reciprocals are presented as something susceptible of a graphical interpretation (a symmetry between two graphs under $y = x$), because graphical interpretation are considered as a fundamental way of conveying meaning. Doing so, everything is fine in the classroom. Students understand what they see on the board because of its graphical nature and mathematics’ morality is safe because reciprocals were used: the reciprocal mathematical concept has been superseded with pedagogical one looking exactly the same at a distance.

Using this double play of concepts at the scale of an entire course results in a deductive architecture that is teared down when looking more carefully. This way of doing mathematics is not to be blamed as such on the teachers. Most of them do not see what is going on with such a course. They are, so to speak, forced into such doings unwillingly, due to the very nature of the ecology they are involved in. Teachers, in our high school that tried to stick to a strict formal mathematical course ended up into the sidings.

This way of doing mathematics “works” to a certain extent because it allows students to learn by heart and teachers to pretend they are giving a genuine mathematical course even if its level is very low. But it doesn’t really work

[2] In some cases, engineers and physicist are allowed to become mathematics teachers.

because concepts taken from the theory of functions such as reciprocals are not meant to be “concrete” the way they are concretized in the course. What do students really learn?

CONCLUSIONS

We have shown that the question of the high failure rates in the course, although of importance, is just the tip of the iceberg, that of the various institutions that impact what a teacher can or cannot do within a mathematical course. In our case, these institutions are the reform and the counter-reform. Taking into account these two allowed us to make sense of the antinomies found in the course and go beyond restrictive interpretations in terms of students’ misbehavior and/or teachers’ inabilities. The high levels of the scale of didactic codetermination convey a message. The impact of individuals, whether they are teachers or students, shouldn’t be underestimated, but the institutional ecology to which they belong must be taken into account if we want to be able to understand various antinomies that cannot be accounted for relying solely on individual behaviors. In this sense, the didactic of mathematics has much insight to gain relying on anthropology and sociology. It is this junction that is put forward in ATD on which we have built on.

Although we feel these preliminary conclusions to be of interest, as mentioned in the introduction, our research isn’t mature yet. We need to be able to position ourselves among the existing literature. It means the following questions should be addressed.

- Have similar conclusions been drawn in other countries?
- How do they articulate with ours if at all?
- If not, what does it mean?
- Does it invalidate our conclusions or does it put into light some peculiarities our high school’s ecology?

Moreover we should look, as stated in our theoretical framework, at different levels of the scale and see if our hypothesis are consistent with other interpretations these other levels allow. This will be the subject of further investigations that will allow us to challenge the phenomenotechnicalty (Schneider, 2013) of our ongoing research.

RECOMMENDATIONS

Issuing recommendations at an early stage of a research is somewhat daring. Nevertheless, we feel this article has something to say about the relationship between teachers and culture. It is common in Belgium to find in initial teacher curricula several courses in epistemology, sociology, etc. that intend to broaden the future teachers’ culture. This broadening is thought, among other things, to allow them to develop a reflective practice that is considered as an important part of today’s best teaching practices (Beckers, 2009). We shall not discuss the relevance of reflective teaching but rather comment on the link between reflective teaching and culture. We feel that a background in epistemology, sociology, etc. does not guarantee that future teachers will engage in reflective teaching. One reason for this is that a course in say epistemology is more likely to constitute an initiation to different epistemologies. But between such a course and the daily routine of teachers there is a not so short distance. We can hardly expect teachers to fill in the gap. As this paper seems to demonstrate in a particular instance, flaws in their practice can result from high level constraints that are not easy to identify nor step aside because they form a context in which the whole education system is nested and they are moreover somewhat evanescent. We conclude from this, the relevance for a course in didactic, to train future teachers to use ATD and/or other didactic theories not as ideologies devised to “teach well” but as systemic and systematic tools designed to highlight the hypothesis underlying their teaching.

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A REVIEW OF RESEARCH ON THE MISCONCEPTIONS IN MATHEMATICS EDUCATION

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ABSTRACT: Misconceptions have been determined as one of the most important bariers on learning mathematics. In this study, it is aimed to investigate and review the articles about misconceptions in mathematics and for this reason conceptual review method was conducted. Within the scope of the study, 21 articles published between 2004 and 2015 were selected through pre-determined criteria. Findings of the review revealed that the number of studies on mathematical misconceptions has increased in the last 5 years. In addition, most of the studies were conducted with primary, elementary and high school students. In these studies researchers generally used multiple choice or open-ended achievement tests. Moreover, most of the studies were conducted for the purpose of determining misconceptions, not eliminating misconceptions. Lastly, some recommendations are provided related to findings of the study.

Keywords: misconceptions, mathematics, concept learning

INTRODUCTION

Progression in educational settings has recently led us to give importance to learning concepts instead of teaching subjects (Posner, Strike, Hewson & Gertzog, 1982). Concept learning begins when the individual comes to the world and continues till the end of life (Ülgen, 2001). However, concept learning is given importance in school programs at every grade level, because learning concepts underlies the learning and cognitive development (Senemoğlu, 2013).

Concepts are perceived as building blocks of knowledge (Altun, 2004), so they reflect the attributes of different objects or facts (Eggen & Kauchak, 1997). We use concepts in all parts of our life when shaping our beliefs, knowledge and actions (Elliott, Kratochwill, Littlefield Cook & Travers, 2000) since they can represent the names of events, thoughts or humans that we encounter in our environment (Kaptan, 1999). According to Demircioğlu (2003), concepts grasp the complexity of knowledge and help us to make sense of both physical and social world.

In order to better provide learning concepts, it is important to know students' prior knowledge and develop new strategies that are appropriate with this knowledge (Akdeniz, Bektaş & Yiğit, 2000). Similarly, Ausubel (1968) advocates that existing conceptual knowledge of students on a specific field can make the most significant impact on the conceptual learning of students. Since learning depends on the cognitive level of learners and complexity of concepts that are to be learned, it is not possible to expect that every individual will learn concepts in the same pace or in a correct way (Fidan, 1999). Thus, in this concept learning process, some students may go off the road and procude misunderstandings which are called as misconceptions (Meşeci, Tekin & Karamustafaoğlu, 2013). There are many definitions of misconception in literature. For example, misconceptions are defined as the perceptions that have very different or wrong meaning from experts' opininon on a certain topic or field (Hammer, 1996). According to Ojose (2015) misconception is a kind of misunderstanding and misinterpretation which is derived from inaccurate meanings.

Misconceptions emerge as a result of experiences and wrong beliefs of individuals (Baki, 1999). Every individual has a unique thinking system which is used in sense-making and expressing the world. If these thinking systems are faulty or deficient, they constitute the bases for misconceptions (Mestre, 1987). As Yağbasan and Gülçiçek (2003) state that if the learner understands a concept as fundamentally different from its scientific meaning, then he/she most probably will construct misconception.

In literature, some studies demonstrated that people cannot distinguish the terms misconception and error (Luneta and Makonye, 2010). According to Eryılmaz and Sürmeli (2002) misconceptions are the subset of errors, which means one can define all misconceptions as errors but all errors may not be misconception. In other words, error is the result of misconception, or misconception is a type of perception which systematically produces error (Smith, diSessa & Roschelle, 1993). Therefore, it is more important that teachers should focus on misconceptions which are the source of errors (Eryılmaz, 2002).

Students bring their perceptions, beliefs and thoughts about the world into classroom (Murphy & Alexander, 2004). When students learn new concepts, they build new knowledge on their previous perceptions, beliefs and thoughts.

That is, if any misconception exists in previous concepts, it is highly that new concepts will include misconceptions as well (Baki, 1999; Driver & Easley, 1978). Thus, as educators we need to know the possible reasons that lie behind these misconceptions and take precautions to provide more efficient learning environments (Ojose, 2015). In other words, determining and eliminating students' misconceptions help teachers understand students' background and perceptions of an academic subject and shape their instructional methods (Murphy & Alexander, 2004).

Misconceptions are very important in learning because students learn new things by relating them with their prior knowledge (Driver & Easley, 1978). Furthermore, most of the misconceptions are deep-seated, widespread and cause permanent obstacles for conceptual understanding (Minstrell, 1982). Since misconceptions are consistent and supported by the individuals' experiences, they steadily resist changing (Cox & Mouw, 1992; Karataş, Köse & Coştu, 2003).

Mathematics is one of the disciplines in which concept learning has an important place, thus many misconceptions might be observed in mathematics. In fact, it is almost impossible in mathematics to define any concept without using many other concepts, since mathematics curricula have a spiral attribute (Ersoy, 2006). Hence, students who have misconceptions in previous topics of mathematics can attach new misconceptions to the previous ones (Şandır, Ubuz & Argün, 2007). For this reason, researchers have been conducting studies on determining and finding ways to eliminate the misconceptions in mathematics for many years (Türkdoğan, Güler, Bülbül & Danişman, 2015). When we search the literature, we realized that there was a lack of review studies which investigate the articles on misconceptions in mathematics. Therefore, this study is thought to fill such a gap and be beneficial for teachers at all grade levels.

Purpose and Research Questions

Learning mathematical concepts highly depends on learning previous concepts so it is important to determine and eliminate misconceptions in mathematics. Therefore, the aim of this review is to investigate and synthesize the literature related to misconceptions in mathematics. Although there are many researches on misconceptions in terms of mathematical concepts, the number of studies that synthesize the studies on misconceptions in mathematics is very limited. Therefore, we tried to find an answer to the question "what are the general characteristics of studies related to misconception in mathematics in national and international field?" On the basis of this research question, answers were searched for the following questions:

1- What kind of misconception studies are conducted in mathematics?
2- Which methods/ways are used in order to determine misconceptions in mathematics?
3- Which techniques are used in order to eliminate the mathematical misconceptions?
4- Which learning areas of mathematics do the studies focus on?

METHOD

In this study, conceptual review/synthesis was conducted in order to investigate the studies related to misconceptions in mathematics. Conceptual reviews are the type of reviews in which the researcher aims to provide an overview of the literature in a given field, including main ideas, models and debates (Petticrew & Roberts, 2006). The synthesis consists of three phases throughout the process: i) Determining the inclusion criteria and review procedure, ii) Reviewing the literature iii) Analysis procedure. These phases will be clarified in detail in the next section.

Determining the inclusion criteria and review procedure

In this phase, we decided on the inclusion criteria, keywords and how we will conduct the review of literature. The inclusion criteria consisted of articles that are i) written in qualitative, quantitative or mixed research methods, ii) published in peer reviewed academic journals rather than a technical report, project anecdote or proceedings, iii) written in English or Turkish language, iv) specifically focused on misconceptions in mathematics, and v) being an empirical research. During the search of literature, we used following keywords in different combinations: *Misconceptions, Concept Learning, Mathematics, Misconceptions in mathematics and Turkish meanings of them (Kavram yanılgıları, kavram öğrenme, Matematik, Matematikte Kavram yanılgıları).*

Reviewing the Literature

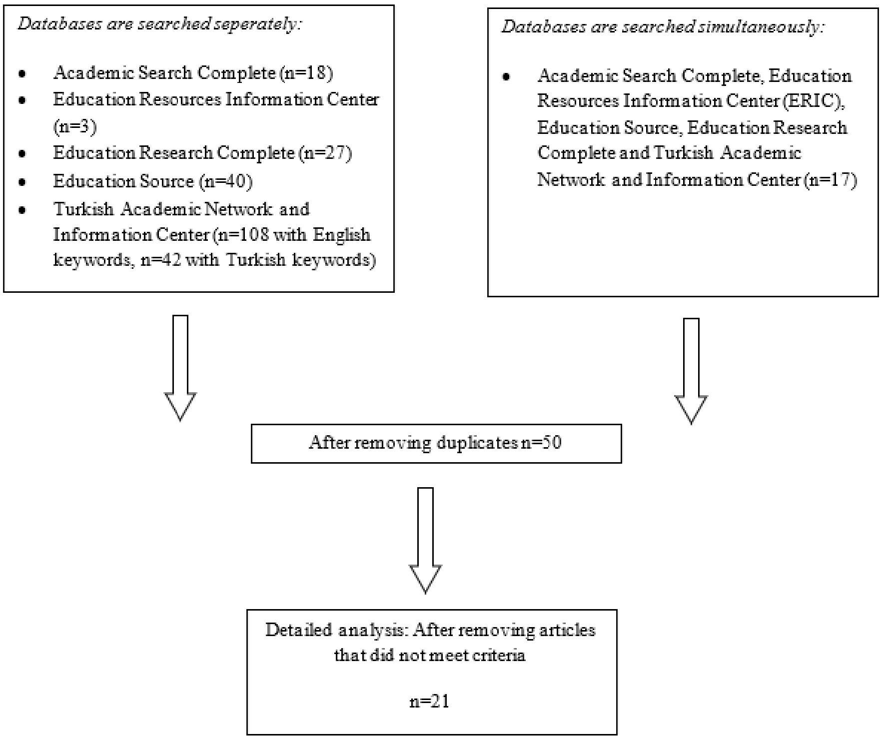
The literature was identified in November and December 2015 by first exploring databases which are more related to educational studies, namely Academic Search Complete, Education Resources Information Center (ERIC), Education Source and Education Research Complete. Then we decided to add database of Turkish Academic Network and Information Center (ULAKBIM) in order to explore literature in the Turkish context.

First, we conducted an advanced search on Academic Search Complete database with keywords “Misconceptions” (in the abstract or Author-Supplied Abstract) and “Concept Learning” (in all text) and “Mathematics” (in the abstract or Author-Supplied Abstract). We filtered the search selecting “academic journals” as source type and “scholarly (peer reviewed) journals”. Although there is no limitation according to publication date, the results demonstrated that studies varied between 1997 and 2015. At the end, we reached 18 studies written in English from this search. Second, we conducted another advanced search on Education Resources Information Center (ERIC) database using similar procedures with the previous one. However, this search brought 3 results which were written in English and published between 2003 and 2012.

Next, we continued with another database namely Education Research Complete. Again, we conducted search with the same keywords and limitations. The results occurred 27 articles written in English and published between 1997 and 2015. Then we conducted search on Education Source database using the same keywords and limitations. The results showed that there were 40 studies published between 1990 and 2015. Two of the studies were written in Turkish and remains were in English. Lastly, we conducted an advanced search on Turkish Academic Network and Information Center (ULAKBIM) with the same procedures. In this search we repeated the procedure with the Turkish meanings of keywords. However, the searching engine of this database did not allow limiting the source type. As a result, we reached 108 results when we searched with the English keywords, and we reached 42 results when we searched with the Turkish meanings of the keywords.

After this procedure, we decided to narrow the search down in order to reach the articles that can be more compatible with the inclusion criteria. Therefore, we selected five databases (Academic Search Complete, Education Resources Information Center (ERIC), Education Source, Education Research Complete and Turkish Academic Network and Information Center) simultaneously. Then we searched the literature with the keywords misconceptions (in the title) and mathematics (in the title), selecting peer reviewed and academic journals. Finally, we reached 17 results published between 1999 and 2015.

We investigated all articles obtained from different databases and keywords. Thus, removing the duplicates from the results, 50 studies published between 1990 and 2015 remained. Those 50 studies were subjected to detailed-analysis and we realized that only 21 of them ensured the inclusion criteria determined before. Remains specifically focused on misconceptions in other disciplines (such as science) rather than mathematics, or they were review studies instead of empirical ones. Therefore, we removed these studies from the analyses and focused on those 21 articles.


Databases are searched seperately:
Academic Search Complete (n=18)
Education Resources Information Center (n=3)
Education Research Complete (n=27)
Education Source (n=40)
Turkish Academic Network and Information Center (n=108 with English keywords, n=42 with Turkish keywords)
Databases are searched simultaneously:
Academic Search Complete, Education Resources Information Center (ERIC), Education Source, Education Research Complete and Turkish Academic Network and Information Center (n=17)
After removing duplicates n=50
Detailed analysis: After removing articles that did not meet criteria
n=21

Analysis Procedure

The remaining articles that are selected in terms of inclusion criteria were organized and coded into Table 1 below, according to their subject domain, context, method, data sources, data analysis, reliability, validity/ trustworthiness, etc.

Table 1. An analysis of studies on misconceptions in mathematics (n=21)

Study	Subject Domain	Subjects	Type	Method	Data Sources	Reliability/Validity, Trustworthiness report	Misconception
Green, Piel, & Flowers (2008)	Arithmetic	Preservice elementary teachers	Implemetation (Pre-test post-test Experimental)	Quantitative	20-Item Mathematics survey, pretest-posttest	Instruments' validities were determined by using expert judgements.	Eliminating Misconception
Almog & Ilany (2012)	İnequalitites	High school students	Survey	Mixed method	Questionnaire, Interviews		Determining misconception
Gningue, Menil, & Fuchs (2014)	Algebra	College remedial students	Implemetation (Pre-test post-test Experimental)	Mixed method	pre-algebra test, four achievement tests, final examination, Informal interviews with students, 24-question likert scale survey	Reliability and validity measures were available for neither the pre-algebra nor the algebra posttests.	Eliminating Misconception
Gür & Barak (2007)	Derivative	High school students	Survey	Quantitative	7-Item open ended test		Determining misconception
Gür (2009)	Trigonometry	High school students	Survey	Mixed method	A diagnostic test that consists of seven trigonometric questions was prepared and carried out. Observations were done.		Determining misconception
Akbayır (2004)	Series (Calculus)	Undergraduate students	Survey	Quantitative	10-item achievement test		Determining misconception
Akkaya & Durmuş (2006)	Algebra	Primary students (6-8 graders)	Survey	Quantitative	30-Item multiple choice test called "Algebra Test" is prepared	Alpha reliability of the test is calculated as 0.74	Determining misconception
Baştürk & Dönmez (2011)	Limit And Continuity	Preservice teachers	Survey	Qualitative and quantitative	A questionnaire which composed of open and closed-ended questions, interviews, observations		Determining misconception

Durkin & Rittle-Johnson (2015)	Numbers	Primary students	Survey	Quantitative	Three measures of misconceptions to assess students' knowledge early in instruction on decimals that measured the: 1) prevalence of misconception errors based on response patterns, 2) existence of misconceptions in a more abstract context, and 3) strength of misconceptions using confidence ratings.		Determining misconception
Kaplan, İşleyen, & Öztürk (2011)	Ratio-Proportion	Elementary students	Survey	Qualitative (Case study)	10- item diagnostic test, interviews	Cronbach alpha reliability of the test was found .61	Determining misconception
Keçeli & Turanlı (2013)	Complex Numbers	Undergraduate students	Survey	Quantitative	17-item complex numbers diagnostic test.	For validity: expert opinions, for reliability: cronbach alpha .84.	Determining misconception
Köklü & Topçu (2012)	Quadratic Functions	High school students	Implemetation (Quasi-Experimental)	Quantitative (quasi experiemtal)	Two-tier diagnostic instrument for parabolas, Cabri.	Cronbach alpha reliability of the test was found .63	Eliminating Misconception
Kula & Bukova Güzel (2014)	Limit	Preservice teachers	Survey	Qualitative (Case study)			Determining misconception
Lin, Ko, & Kuo (2014)	Algebra	Preservice teachers	Implementation (Pre-test post-test control group d. Experimental)	Quantitative (pre-test posttest control group design)	The Algebraic Misconceptions Test (AMT) and The Attitudes Toward Computers and Mathematics Teaching Questionnaire (ATCMT)	Feedback received from experts, cronbach alpha is found .86 (for test) and .90 (for questionnaire)	Determining misconception
Lin, Yang, & Li (2015)	Numbers	Elementary students	Survey	Quantitative	50-item web-based two-tier test	Two experts in the field of mathematics education reviewed the WTTT-NS items for face and content	Determining misconception

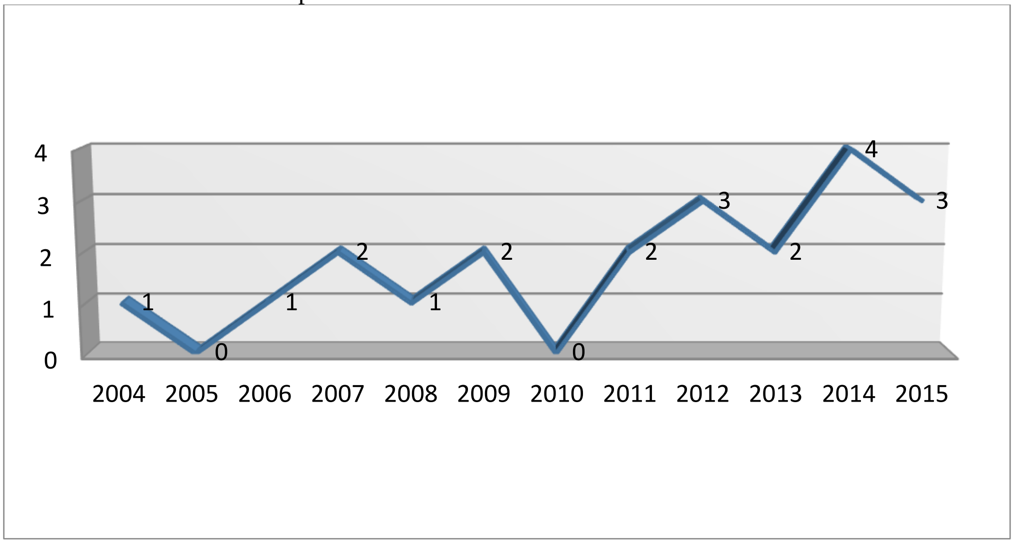
						validity; Cronbach α was found .877	
Muzangwa & Chifamba (2012)	Calculus	Undergraduate students	Survey	Quantitative	10-item test	KR-20 reliability is .31	Determining misconception
Pesen (2007)	Fractions	Primary students (3rd graders)	Survey	Field research and diagnosis method was used	24 item Diagnostic test was used	Class teachers and experts' view to provide validity and reliability of the diagnostic test. Alpha is .90	Determining misconception
Tuna (2013)	Trigonometry	High school (10th grade)	Implementation (Quasi-Experimental with control group)	Quantitative (a quasi-experimental design with control group was used)	14-item test	.	Eliminating Misconception
Türnüklü (2014)	Quadrilaterals	Preservice teachers	Survey	Qualitative (Document analysis)	The data was obtained by the lesson plans which were prepared by the participants	.	Determining misconception
Yang & Lin (2015)	Numbers	Elementary students (5th graders)	Survey	Quantitative	40-item number sense four-tier test	In order to ensure the validity of the instrument, the researchers explained to students how to answer items in the online test system before they started to answer the items.	Determining misconception
Erbaş, Çetinkaya, & Ersoy (2009)	Linear Algebraic Equations	High school students	Survey	Quantitative	56-item Linear equation test	Guttman split half: .95; cronbach alpha: .96	Determining misconception

FINDINGS

Trends in the literature on misconception in mathematics

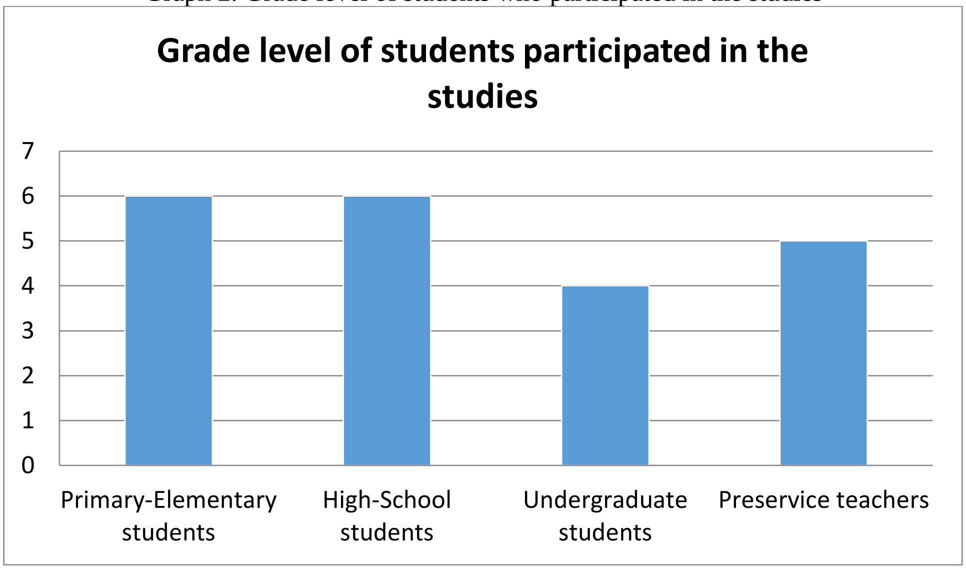
The articles examined were published between the years 2004 and 2015. According to Graph 1, it can be stated that there is an increase in the number of studies conducted on misconceptions in mathematics in recent years. We can obviously see that more than half of the articles have been published especially in the last five years.

Graph 1. Publication trends from 2004 to 2015



The studies were conducted on varied grade levels. According to Graph 2, the participants of six studies were primary and elementary students. Similarly, six studies were conducted with high school students. However, the participants of remaining studies (nine studies) were undergraduate students; in fact five of these were conducted with pre-service teachers.

Graph 2. Grade level of students who participated in the studies



The learning areas examined in the studies differed as well. As shown in Graph 3, the majority of the studies were related to *algebra* and *numbers* topics (n=3 for each). In addition, *derivative*, *trigonometry* and *limit* concepts were investigated in many of the studies (n=2 for each). Other learning areas investigated were *linear algebraic equations*, *arithmetic*, *inequalities*, *series*, *ratio-proportion*, *quadratic functions*, *fractions*, and *quadrilaterals* (n=1 for each).

The main purpose of the studies on misconceptions in mathematics: Eliminating or determining?

The studies were investigated in terms of whether they have just determined the types of misconceptions on a certain learning area or they have investigated the ways to eliminate these misconceptions. However, all studies except four studies had the purposes to determine what misconceptions students had on a specific mathematics subject, while only four studies applied an intervention in order to see whether the instructional technique or method was effective on eliminating the current misconceptions. For instance, Tuna's (2013) study compared the effect of the 5E model and traditional teaching methods on elimination of misconceptions about trigonometry concepts. The results demonstrated that the 5E model had an effect on non-emergence of misconceptions on trigonometry topic among students. In another study, Green, Piel, and Flowers (2008) investigated that manipulative-based instruction can efficiently and effectively help decrease the misconceptions in arithmetic and increase students' knowledge. Similarly, Gningue, Menil and Fuchs (2014) revealed that using virtual manipulatives helps students overcome misconceptions about algebra and pre-algebra concepts more easily. In the study of Koklu and Topcu (2012), it was found that the misconception scores and achievement scores of students who learned in Cabri-assissted learning environment were better compared with students' who were in traditional classroom.

Common data collection tools to determine misconceptions in mathematics

More than half of the studies included single data collection tool, while few of the studies were conducted using more than two tools. Among 22 studies, 15 studies used achievement or diagnostic tests. In these tests, 2 tests were designed as two-tiered (Koklu & Topcu, 2012; Lin, Yang, & Li, 2015) and 1 test was designed as four-tiered (Yang & Lin 2015). Researchers obtained data through lesson plans prepared by participants in 2 of the studies (Kula & Bukova-Güzel, 2014; Türnüklü, 2014). In addition, questionnaires were used to determine students' misconceptions in 3 studies (Almog & Ilany, 2015; Baştürk & Dönmez, 2011; Lin, Ko, & Kuo, 2014). Lastly, in 5 of the studies, interviews were conducted with participants in order to collect data (Almog & Ilany, 2015; Gningue, Menil, & Fuchs, 2014; Baştürk & Dönmez, 2011; Kaplan, İşleyen, & Dönmez, 2011; Kula & Bukova-Güzel, 2014).

DISCUSSION AND CONCLUSIONS

This systematic review of 21 articles on misconceptions in mathematics is conducted due to the lack of synthesis in the national and international context. Findings revealed the general approaches adopted in the studies in terms of participants, grade level, purpose, data collection tools and learning areas of mathematics which are investigated. First, the review found out that in recent years there is an increase in the number of studies about misconceptions on mathematics. Actually, this result is congruent with the findings of the study conducted by Türkdoğan, Güler, Bülbül and Danişman (2015), since the number of studies investigated in that study showed an increase in the last five years (between 2008 and 2013).

Second, most of the studies were conducted with primary, elementary and high school students, while less than half of the studies were conducted with undergraduate students. According to Duran (2013), during initial grades students learn many basic concepts in order to be aware of latter mathematics concepts, so researchers might have taken the road from this point of view and selected younger ages as participants.

This study revealed that articles investigated misconceptions on similar topics or learning areas of mathematics. While algebra and number sense are the most common subjects in primary and elementary classes, trigonometry, derivative and limit concepts are the most common topics in high school and higher education. In the related literature, although it is advocated that students have lots of misconceptions in many geometry topics (Dobbins, Gagnon & Ulrich, 2014), only misconceptions on quadrilaterals topic were investigated in one of the articles.

Most of the studies investigated in this review used traditional one-tier achievement tests. However, Peşman (2005) states that wrong answers given in these tests can be considered as misconceptions although they are not. Students can give wrong answer due to lack of knowledge, wrong information in the question or faulty thinking during the test, but these do not prove that student has misconceptions on that concept (Tunç, Akçam & Dökme, 2011). Therefore, tests that include more than two tiers are stated to be more appropriate to be able to detect the misconceptions (Peşman, 2005). However, it seems that very few studies took into consideration this point. In addition, one of the most appropriate ways to determine students' misconceptions is collecting qualitative data through interview or observation, since they provide in-depth information about students' knowledge. However, it is observed that only less than half of the studies used such methods in this review.

The results of this review proved that most of the studies were conducted for the purpose of determining students' misconceptions instead of eliminating them. Although determining is the first step of eliminating the misconceptions, the researchers did not prefer going on further steps. Since people resist to the idea that their beliefs or thought are not correct, changing their concepts and eliminating misconceptions are not that easy (Comins, 1998). In addition, according to Sander (1993) it is too difficult to eliminate misconceptions through traditional learning and teaching techniques. Therefore, only few of the studies applied a treatment to see whether the treatment was able to eliminate students' present misconceptions.

Recommendations for Future Research

The major aim of the research on misconceptions in mathematics should move beyond just determining them. First of all, as educators we need more effective instructional methods which can prevent the arising of such misconceptions and eliminate the present misconceptions. Before this, it is also important to detect these misconceptions using correct tools. Therefore, researchers should be aware of which assessment techniques or data collection instruments are better at determining specific mathematics misconceptions.

This review investigates limited number of articles related to mathematics misconceptions. Thus, further review studies can be conducted to enlarge and overview more on misconception research. Especially in undergraduate level, there is a lack of studies related to mathematics misconceptions. In the related literature, teachers are stated as one of the reasons for misconceptions since they use inappropriate instructional methods or have lack of knowledge (Tekkaya, Çapa & Yılmaz, 2000). Hence, researchers can conduct more studies about in-service and pre-service teachers.

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MATHEMATICS EDUCATION IN SOUTH AFRICA: MANY PERSPECTIVES, MANY VOICES

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ABSTRACT: Mathematics education and its perceived significance as a foundation of national economic competitiveness have become a topic of intense scrutiny and debate in many countries. Researchers, government officials, and the media in South Africa bring to this debate their respective concerns, perspectives, recommendations, and voices. This study used automated textual analysis and visualization technologies to search a collection of 148 scholarly articles, dissertations and books, government-related publications, and media reports about mathematics education in South Africa for evidence of recurring, distinctive voices characteristic of these communities of thought and action. The analysis found that these communities characteristically do favor the use of different concepts in representing their concerns, perspectives, and recommendations. Characteristic preferences are also observed with respect to clusters of concepts, called themes. These and other findings are presented in both tabular and graphical formats.

Keywords: mathematics, education, perspectives, automated textual analysis, leximancer

INTRODUCTION

Much of what humanity knows and believes is expressed and preserved as unstructured data. We use text, graphics, and music to tell the stories of our lives, explain the history of the universe, and to reveal our thoughts and feelings. Our storehouse of knowledge and experience is vast, complex, messy, and growing exponentially. To cope with the information explosion, scholars in many knowledge domains rely on sophisticated information technologies to search for and retrieve records and publications pertinent to their research interests. But what is a scholar to do when a search identifies hundreds of documents, any of which might be vital or irrelevant to his/her work? More and more, scholars are turning to automated content analysis technologies to achieve what they do not have time to do themselves; characterize the global features of a large corpus of work and identify relationships between significant concepts and themes.

There are several reasons why one would want an automated system for content analysis of documents (Smith & Humphreys, 2006). Researchers are subject to influences that they are unable to report (Nisbett & Wilson, 1977) which may lead to subjectivity in data analysis and the interpretation of findings. Limiting researcher subjectivity often involves extensive investments of time and money to address interrater reliability and other sources of bias. One goal of automated content analysis is to reduce this cost and to allow more rapid and frequent analysis and reanalysis of text. A related goal is to facilitate the analysis of massive document sets and to do so unfettered by *a priori* assumptions or theoretical frameworks used by the researcher, consciously or unconsciously, as a scaffold for the identification of concepts and themes in the data (Zimitat, 2006). Since textual analysis technologies operate directly on words (as well as other symbols), a rationale for inducing relationships between words is needed. Beeferman observed that words tend to correlate with other words over a certain range within the text stream (Beeferman, Berger, & Lafferty, 1997). Indeed, a word may be defined by its context in usage (Smith and Humphreys, 2006, p. 262; Courtial, 1989; Leydesdorff and Hellsten, 2006; Lee and Jeong 2008).

Mathematics education and its perceived significance as a foundation of national economic competitiveness has become a topic of intense scrutiny and debate in many countries. Educators, researchers, government officials, the private sector, and the media bring to this debate their respective concerns, perspectives, recommendations, and voices. Motivated by a hunch that different communities of thought and action tend to speak with distinctive voices, this study used automated textual analysis and visualization technologies to search a collection of 148 recent (2011 – 2015) journal articles, dissertations and books, South African research organizations, Opinion Pieces on the Ministry of Education website, and Media24 reports identified by their use of the keywords *mathematics*, *education*, and *South Africa* for evidence of recurring, distinctive voices.

Research Questions

This study asks the following research questions relative to a sample of 148 documents (i.e., files) identified and downloaded from a variety of online sources:

1. Which concepts
   1.1. Occur most frequently?
   1.2. Co-occur most frequently?
   1.3. Are associated with particular communities of thought and action?
2. What themes (i.e., co-occurring sets of concepts) emerge?

METHOD

This is an informal survey of professional and public discourse relative to mathematics education in South Africa. Metaphorically, the study casts a wide net into an ocean of unstructured data to identify recurring concepts and themes associated with the ongoing debate of mathematics education in South Africa. All documents were analyzed using *Leximancer* (2015), a textual analytics tool that automatically extracts a dictionary of terms from source documents, discovers concepts, and constructs a thesaurus of terms associated with each concept. *Gephi* was then used to visualize and further explore these networks of concepts as identified in Leximancer.

In *Leximancer*, concepts are collections of words that "travel together" (i.e., co-occur) throughout the text. For example, in a document about climate change, the concept *carbon* might, in the thesaurus, be associated with the keywords *dioxide, carbonate, footprint*, and *sequester*. *Leximancer* weights these terms according to how frequently they occur in sentences containing the concept, compared to how frequently they occur elsewhere. A sentence (or group of sentences) is only tagged as containing a concept if the accumulated evidence (the sum of the weights of the keywords found) is above a set threshold. These data are used to make two determinations: (i) the most frequently used concepts within a body of text; and more importantly, (ii) the relationships between these concepts (e.g., the co-occurrence between concepts). Discovered concepts may be displayed in ranked lists, by frequency of occurrence, or in graphical format. This approach to concept discovery, in addition to being unbiased, relieves scholars of the task of formulating their own coding schemes, while permitting the introduction of undiscovered terms at the scholar's discretion.

Leximancer discovers and extracts thesaurus-based concepts directly from the text data (Smith and Humphreys, 2006) using Boolean algorithms. Consequently, concepts are robust statistical artifacts. These concepts are then coded into the text (i.e., tags are inserted) using the thesaurus as a classifier. This process employs two stages of co-occurrence information extraction—*semantic* and *relational*—using a different algorithm for each stage. Clusters of co-occurring concepts are then aggregated into themes. The algorithms used are statistical, but they employ nonlinear dynamics and machine learning. The resulting asymmetric concept co-occurrence information is then used to generate a concept map and tabular outputs. For an over view of Leximancer features see Thomas (2014).

Leximancer processes text in a series of four stages: Load Data, Generate Concept Seeds, Edit Emergent Concept Seeds, Develop Concept Thesaurus, Create Compound Concepts, Generate Thesaurus, and Run Project. Figure 1 shows the Leximancer Project Control Panel.

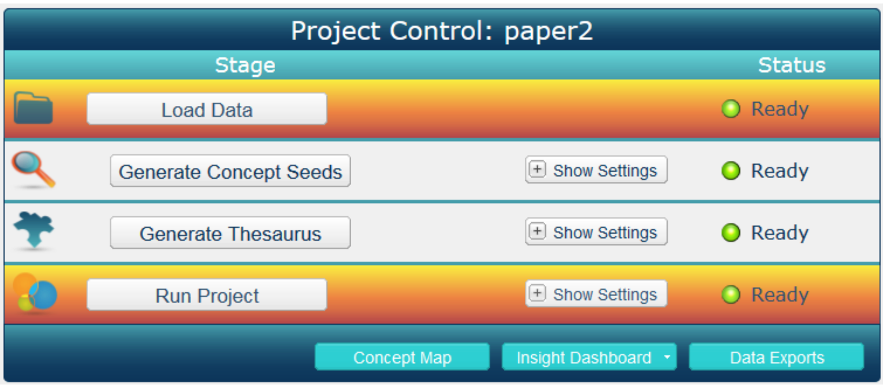


Figure 1. Leximancer Project Control Panel

At each stage, Project Control prompts the researcher to edit the manner in which *Leximancer* processes the data. The editing options provided at each of these stages enable the researcher to, in effect, change the size of the "sliding window", add or delete documents, merge similar concepts (e.g., student, students, pupils), delete irrelevant or distracting concepts (e.g., recurring formatting terms like *Figure* and *Table*), propose additional concepts, and so on. All such choices are reversible, so experimentation is both possible and desirable in refining the analysis and presentation graphics.

Sampling and Selection of Documents

The sample of documents used in this study is neither random nor formally systematic. No generalizations are made about the population based on the characteristics of the sample. Documents associated with different communities of thought and action were identified. The research assumption of this paper was that *researchers' perspectives* about mathematics in South Africa are reflected by articles about mathematics in three South African journals published by different research organizations in 2014 and 2015:

- South African Journal of Education, the official journal of the Education Association of South Africa
- African Journal of Research in Mathematics, Science and Technology Education, the official journal of the Southern African Association for Research in Mathematics and Science Education (SAARMSTE)
- Pythagoras, the official journal of the Association for Mathematics Education of South Africa (AMESA)

The second assumption was that the *government's voice* about mathematics in South Africa are reflected by:

- *Media statements* about school mathematics in 2014 and 2015 by Angie Motshekga, the minister of Basic Education.
- Publications about mathematics education by the *Human Sciences Research Council*, South Africa's statutory research agency.
- Publication about mathematics education by *JET Education Services*, an independent, non-profit organization that works with government, the private sector, international development agencies and education institutions to improve the quality of education and the relationship between education, skills development and the world of work.

The third and last assumption was that the media's voice about mathematics in South Africa is reflected by:

- News paper reports about school mathematics in the archives the website of *Media24*, the largest media house in South Africa. Media 24 is a division of the South African media company Naspers.

Table 1 lists the number of documents associated with each community of thought included in the sample and their respective labels in the figures and tables in this paper.

Table 1. Number of documents included in sample

Community of Thought and Action	Label	#
Human Sciences Research Council	hsrc	8
JET Education Services	jet	9
South African Journal of Education	sage	15
African Journal of Research in Mathematics, Science and Technology Education	ajr	18
Pythagoras	pythagoras	15
Media24	media	74
Opinion Pieces by Minister Angie Motshekga	motshekga	9

RESULTS AND FINDINGS

Concepts

Leximancer depicts concept relationships in graphical representations called network spanning trees (See Figure 2). In such trees, concept nodes, individual files, and file folders appear as circular nodes. Rather than plot all 148 file nodes (which would hopelessly clutter figures), only the 7 file folders (e.g., hsrc, media, etc.) and 60 discovered concepts are plotted. The position of each folder reflects the aggregated concepts of its constituent files. In *Leximancer* network spanning trees, co-occurrences appear as segments. Concept proximity is strongly related to concept co-occurrence, that is, concept nodes positioned near to one another co-occur more frequently than more widely separated concepts. But the edges in *Leximancer* network spanning trees indicate only the most likely co-occurrences associated with each concept. All co-occurrences are seen in Figure 3. This *hair ball* representation was created using *Gephi* (2015), a network visualization tool.

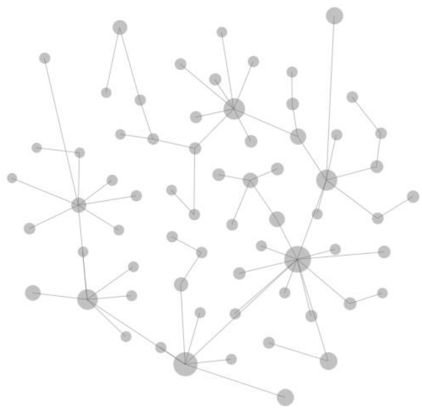


Figure 2. *Leximancer* Network Spanning Tree

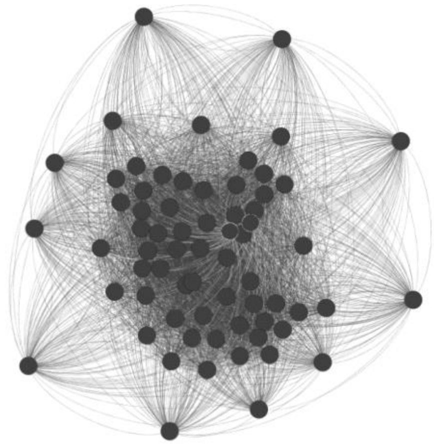


Figure 3. *Gephi* Network

In Figure 4, all discovered concepts and file folders appear as node labels. The 20 most frequent concepts occurring across the entire data set appear in Table 2. Count refers to the frequency of occurrence of a concept. Relevance is the percentage frequency of text segments which are coded with that concept, relative to the frequency of the most frequent concept in the list.

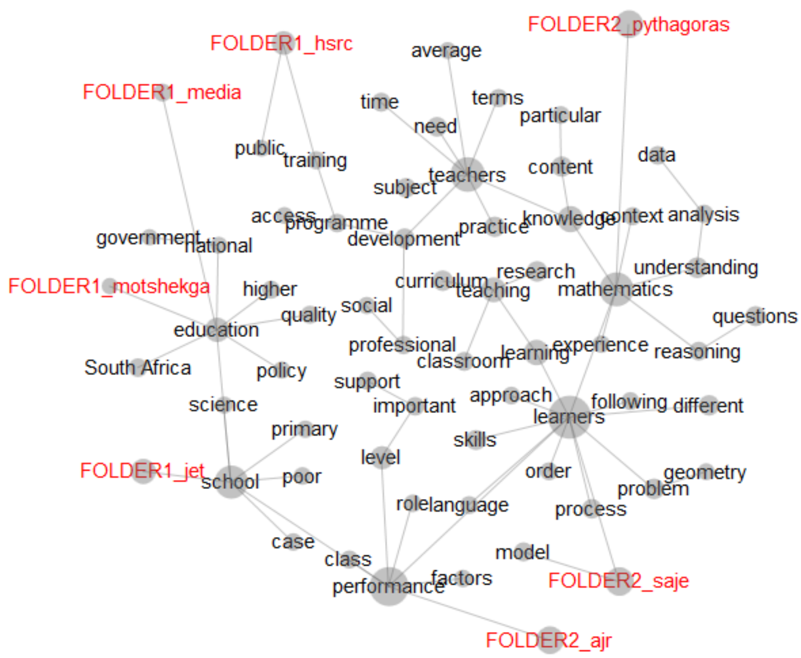


Figure 4. Concepts and Folders

Table 2. The 20 most frequent concepts across all the documents

	Concept	Count	Relevance		Concept	Count	Relevance
1	learners	4201	100%	**11**	different	875	21%
2	performance	3854	92%	**12**	problem	850	20%
3	mathematics	2770	66%	**13**	questions	829	20%
4	teachers	2668	64%	**14**	understanding	820	20%
5	school	2642	63%	**15**	research	791	19%
6	knowledge	1388	33%	**16**	curriculum	717	17%
7	learning	1320	31%	**17**	practice	698	17%
8	education	1288	31%	**18**	process	670	16%
9	teaching	1221	29%	**19**	need	665	16%
10	level	1137	27%	**20**	skills	664	16%

- Research questions 1.1 asks, which concepts occur most frequently across the entire document set? The answer to this question is found in Table 2: *learners, performance, mathematics, teachers, school, knowledge, learning, education, teaching, level, different, problem, questions, understanding, research, curriculum, practice, process, need,* and *skills*.
- Research question 1.2 asks, which concepts co-occur frequently? The answers to this question are implicit in Figure 4. For instance, the proximity of *government* and *national* suggests that they co-occur frequently. The same may be said of the concepts *mathematics* and *understanding*. The figure also suggests that the concepts *government* and *understanding* are unlikely to co-occur frequently.
- Research question 1.3 asks, which concepts are associated with particular communities of thought and action? The answers to this question are found in Tables 3 – 6.

Table 3. Most frequent concepts: *hsrc* and *jet*

	hsrc				***jet***		
	Word-like	Count	Likelihood		Word-like	Count	Likelihood
1	government	97	44%	**1**	professional	180	41%
2	training	147	37%	**2**	government	87	39%
3	public	93	37%	**3**	school	890	34%
4	higher	130	32%	**4**	policy	95	31%
5	quality	109	29%	**5**	training	121	31%
6	access	72	29%	**6**	poor	98	30%
7	national	74	28%	**7**	primary	84	27%
8	programme	132	27%	**8**	national	71	27%
9	social	64	23%	**9**	education	337	26%
10	policy	69	23%	**10**	case	105	26%

Table 4. Most frequent concepts: *sage* and *ajr*

	sage				***ajr***		
	Word-like	Count	Likelihood		Word-like	Count	Likelihood
1	model	228	41%	**1**	geometry	152	53%
2	role	127	37%	**2**	problem	307	36%
3	factors	112	34%	**3**	factors	117	36%
4	skills	226	34%	**4**	context	143	33%
5	learning	412	31%	**5**	experience	106	32%

6	policy	90	30%	**6**	curriculum	203	28%
7	reasoning	151	27%	**7**	mathematics	781	28%
8	content	167	27%	**8**	understanding	231	28%
9	learners	1102	26%	**9**	questions	232	28%
10	class	119	26%	**10**	process	187	28%

Table 5. Most frequent concepts: *Pythagoras* and *Media 24*

	pythagoras				***media***		
	Word-like	Count	Likelihood		Word-like	Count	Likelihood
1	understanding	322	39%	**1**	science	75	23%
2	analysis	218	39%	**2**	national	33	12%
3	average	136	38%	**3**	language	42	11%
4	reasoning	184	33%	**4**	subject	57	10%
5	particular	131	33%	**5**	need	63	09%
6	context	140	33%	**6**	education	118	09%
7	data	187	32%	**7**	school	236	09%
8	questions	260	31%	**8**	training	34	09%
9	different	274	31%	**9**	programme	40	08%
10	content	192	30%	**10**	time	50	08%

Table 6. Most frequent concepts: *motshekga*

	motshekga		
	Word-like	Count	Likelihood
1	quality	39	10%
2	national	23	09%
3	support	27	06%
4	access	15	06%
5	subject	32	06%
6	education	70	05%
7	programme	26	05%
8	public	12	05%
9	development	28	05%
10	social	12	04%

Themes

Unlike concepts, which are unbiased statistical artifacts, themes are clusters of concepts that reflect the intent and interests of the researcher. For example, consider Figure 5. Two circles sketched informally by the authors suggest clusters of concepts that frequently co-occur with *schools* and *mathematics*. *Leximancer* performs clustering automatically and analytically while providing the researcher a measure of control over the way the themes are displayed. Figure 6 illustrates this approach to include all sample documents. Theme names correspond to the most frequently occurring concept in the theme. Alternatively, Figure 7 lists the themes and their comparative relevance while Table 6 identifies the concepts subsumed under each theme. Figure 8 displays all concepts, themes, and folders.

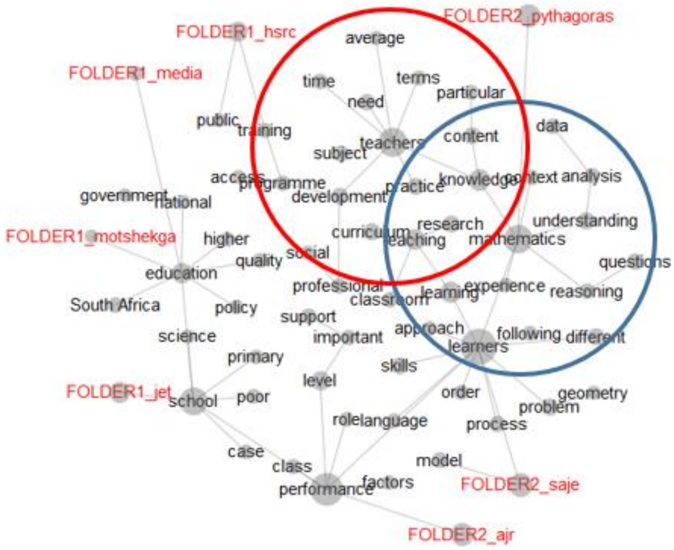


Figure 5. Themes Sketched by Authors: *teachers* and *learners*

Research question #2 asks, “What themes (i.e., co-occurring sets of concepts) span the concepts in a useful manner?” Figures 6, 7, and 8 and Table 7 identify a set of themes that aggregate concepts into categories resonate with important elements of mathematics education discourse. This set of themes serves the authors’ purpose in making that connection.

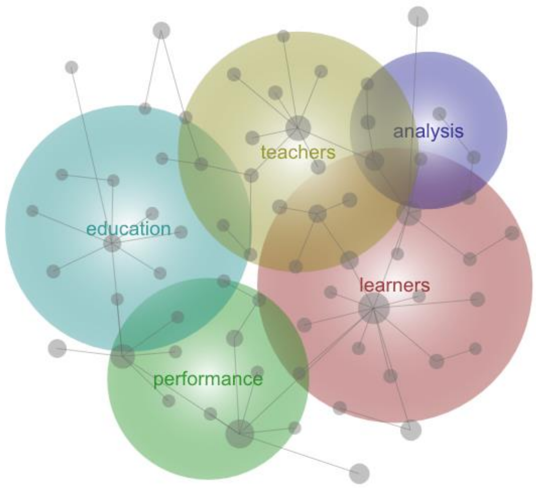
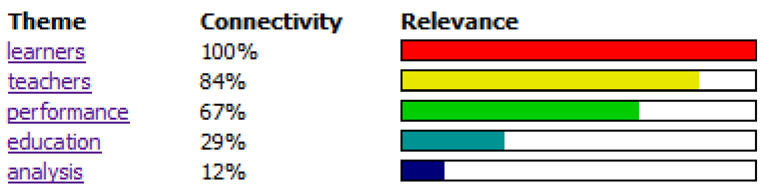


Figure 6. Themes Spanning the Entire Data Set



Theme	Connectivity	Relevance
learners	100%	
teachers	84%	
performance	67%	
education	29%	
analysis	12%	

Figure 7. Theme Connectivity & Relevance

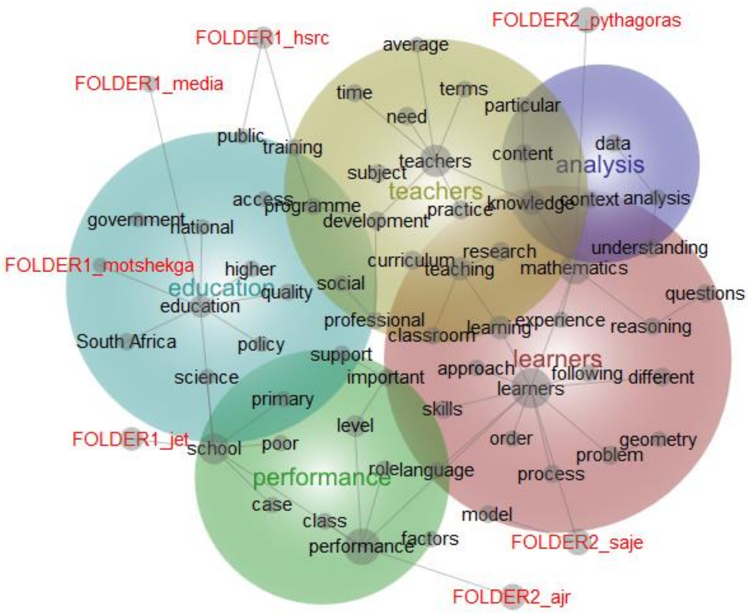


Figure 8. Themes, Concepts, and Folders

Table 7. Themes & Associated Concepts

Theme	Concepts
learners	learners, mathematics, learning, understanding, problem, different, skills, questions, process, model, classroom, reasoning, order, following, approach, experience, geometry
teachers	teachers, knowledge, teaching, research, curriculum, practice, content, development, need, subject, time, program, professional, training, terms, average
performance	performance, school, level, important, support, class, language, role, poor, factors, case, primary
education	education, South Africa, quality, higher, policy, social, science, national, access, public, government
analysis	analysis, data, context, particular

DISCUSSION

Some longtime users and consumers of conventional statistical methods find it difficult to see the purpose, value, or even the validity of textual (i.e., content) analyses of unstructured data (e.g., documents, interview transcripts, blog postings). For instance, when data take the form of words rather than numbers, how are research questions, hypotheses, sampling, data analysis, and conclusions related? Hypothesis testing and its attendant concerns with sampling, bias, error estimates, and other measures of uncertainty appear to have little or no traction in textual analysis. And while a deeper gaze into *Leximancer* reveals that it is based on Bayesian thinking, this insight offers little comfort to researchers unfamiliar with Bayesian methods and purposes.

This paper asks and answers questions about the content of 148 documents using *Leximancer*, an automated qualitative approach founded on Bayesian methods. In this study, data acquisition, management, and analysis are focused on the identification of recurring concepts, their relationships to one another (i.e., co-occurrence and themes), and the communities of thought and action (e.g., publications) from which they were drawn. The goal of this inquiry is to determine whether different communities of thought and action favor the use of different and/or distinctive language (i.e., concepts) in representing their interests, findings, and recommendations. In a time when clear communication among stakeholders is needed to build consensus, understanding and accommodating these differences is essential if mathematics education in South Africa is to speak with a unified voice.

Leximancer identified a total of 60 recurring concepts in 148 documents drawn from 7 communities of thought. The identification and graphical representation of these concepts was performed automatically with limited editorial oversight (e.g., merging word variants) by the authors. This approach dramatically limits researcher bias in the identification of concepts and determining their locations in graphical representations (see Figure 4). Concepts determined in this manner are robust statistical artifacts, reliably and consistently identified in repeated analyses of the document sets. Repeated analyses do not necessarily yield identical graphical representations, however. Each variant on the network spanning tree displays the relationships between concepts from a different perspective, so to speak. For instance, the tree might be rotated, reflected, dilated, sheared, or otherwise rearranged in a manner that at first glance appears substantively different, but which on closer inspection portrays the same information in a different layout, including the relative positions the folders.

The answer to the research question 1a, “Which concepts occur most frequently?” was generated automatically by *Leximancer*: learners, performance, mathematics, teachers, school, knowledge, learning, education, teaching, level, different, problem, questions, understanding, research, curriculum, practice, process, need, and skills. These concepts appear in Table 2, where Count refers to the frequency of occurrence of a concept, and Relevance is the percentage frequency of text segments which are coded with that concept, relative to the frequency of the most frequent concept in the list, learners. This table also makes it clear that the first 5 concepts in the table are most characteristic of the data.

The answer to research question 1b, “Which concepts co-occur most frequently?” is more difficult to characterize. In Figure 4, concepts that are near to one another co-occur more frequently that more widely separated concepts. This representation suggests at a glance which concepts co-occur frequently without leaving out any information. In other words, Figure 4 is not so much a definitive answer to the research question as it is a model of co-occurrence from which specific inferences may be drawn. So, one answer to this question is, “The concepts located near one another in Figure 4”.

Alternatively, a table containing frequency of co-occurrence data could be created. Table 8, which shows the co-occurrence of the 10 most frequently occurring concepts, would be over 36 times as large if all concepts were included. Massive tables, while they have their uses, are not particularly helpful in this context.

Table 8. Partial co-occurrence matrix

	learners	performance	teachers	mathematics	school	knowledge	learning
learners		1626	1024	1228	1009	562	675
performance	1626		746	883	1056	371	401
teachers	1024	746		765	728	646	375
mathematics	1228	883	765		518	498	445
school	1009	1056	728	518		206	299
knowledge	562	371	646	498	206		208
learning	675	401	375	445	299	208	

The answer to research question 1c, “Which concepts are associated with particular communities of thought and action (i.e., folders)?” is based on the proximity of concepts and folders in Figure 4. One answer to this question is, “Concepts located near a particular folder are more characteristic of the documents in that folder than concepts located further away. Documents in folders widely separated from one another emphasize the use of different concepts. These differences are apparent in Tables 3 – 6, which identify the most frequent concepts in each folder. As with co-occurrence, this representation is not so much a definitive answer to the question as it is a model from which specific inferences may be drawn.

Discovered concepts and themes by themselves offer little more than labels for important ideas and their associations. The ideas themselves are embedded in the context blocks tagged by *Leximancer* in the source documents. As such, each concept is directly linked to the context blocks where it occurs. Boolean searches may be used to focus on specific co-occurrences of concepts. For example, a search for text blocks containing the concepts *learners* and *teachers* and *performance* and *education* and *analysis* pointed to 4 text blocks, all from the same HSRC document.

Despite widespread acceptance of the notion that improving student performance may have a high economic and social payoff, policy analysts in all countries have surprisingly limited hard data on which to base educational strategies for raising achievement. In South Africa this question is all the more pressing. South African students score at low levels in mathematics and language tests even when compared with students in other African countries. Further, the South African government’s own evaluations of ten years of democracy show little improvement in educational outcomes despite significant policy changes. While some reasons for this poor performance may be evident, and there is widespread agreement that the main challenge in South Africa is the quality of education, there is little empirical analysis that helps policy makers understand the low level of student performance in South African schools or how to improve it.

Depending on a researcher's interests, the same set of documents can be searched for text blocks containing particular sets of concepts. Those text blocks reveal context and purpose in ways that the concept lists themselves cannot. Viewed in this manner, textual analytics technologies like *Leximancer* offer more than summary findings. They provide a dynamic modeling environment for continued exploration and discovery.

In a subsequent article, similarities and differences between the document sets will be explored in greater depth and the broader implications of automated textual analysis in mathematics education research will be considered.

LIMITATIONS

In *Leximancer*, themes are variable concept groupings used to facilitate data exploration. Unlike concepts, which are robust statistical artifacts, themes are conveniences imposed by the researcher. The themes and subsumed concepts seen in Figure 8 and Table 7 reflect the authors' subjective preferences in this study.

In selecting sample documents for this study, several methodological issues arose for which the authors could find no clear guidance. For instance, selecting sample documents for content analysis is inherently different than selecting sample measurements for statistical analysis. We wondered on what basis a 500-word news story and a 5000-word research report might be considered comparable data. We settled on this interpretation: the most important determination with regard to a particular concept is whether it is present in a given document (and therefore characteristic of the community of thought from which the document was drawn), not how many times it occurs. Longer documents provide more opportunities to detect the co-occurrence of different concepts. Whether a concept occurs only once or many times in a particular document, that concept is formally associated with the document and its community of thought.

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INFINITY AS A MATHEMATICS EDUCATION PLAYGROUND

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ABSTRACT: Infinity is a profound concept, and hence a potent educational context for triggering mathematical thinking. Building on previous research concerning the ability of students to make sense of infinity, we ask how we could think about infinity as a mathematical playground. The infinity 'equipment' we have been designing for our mathematical 'playground' now constitutes a range of inquiry-oriented activities, all at varying stages along the design-experiment continuum. For this paper, we will consider activities built from Zeno's paradoxes and Cantor's cardinality of sets. Our work with children and young adults leads us to suggest a radical position: that infinity is indeed a playground for legitimate thinking, regardless of the content outcomes of that thinking.

Keywords: mathematics instruction, mathematical experience, mathematical thinking, infinity

INTRODUCTION

Infinity – both the infinitely small and large – is a profound topic; one that can inspire paradoxes and ingenuity. Philosophers, theologians, scientists and mathematicians throughout history have grappled with the topic (Clegg, 2003; Eves, 1960). Aristotle conceived of the infinitely large as a potential, where an absolute infinity does not exist. To refute the notion of the universe as infinite, Archimedes invented base-ten exponential notation so that he could extend counting from a small measure of poppy-seeds to encompass all matter. Galileo's attempt to tame the infinitely small by describing it as immeasurably small served as a precursor to the infinitesimals developed by Newton and Leibniz and effectively critiqued by Bishop Berkeley. Modern mathematicians have developed transfinite arithmetic, in an attempt to resolve paradoxes such as Hilbert's Hotel Infinity. Infinity is a rich playground for thinking from various perspectives. This paper takes up the potential of infinity as a playground for thinking by children and young adults.

Others have considered the thinking of young adults when confronted with the profoundness of infinity, such as paradoxes that arise when trying to make sense of the infinite. This research is often framed in terms of how to shift student's intuitive notions of infinity (e.g., as a process or potential) toward accepted mathematical results (e.g., infinity as an absolute). Tsamir (2001), for example, used varying representations of the same comparing-infinite-sets task as an educational context for secondary school students to recognize inconsistencies in their thinking and thereby take-up one-to-one correspondence as a method of comparing infinite sets. (See also Meconi, 1992). This work was extended by Mamolo and Zaskis (2008), who found that intuitive notions of infinity are a conceptual barrier that university students must overcome along a learning trajectory toward resolving infinity paradoxes, such as Hilbert's Hotel Infinity, in ways consistent with current mathematical thinking.

The work of Ely (2010) moves toward the notion that infinity can be a playground for thinking, rather than a difficult concept to understand because of conceptual barriers to moving from intuitive to mathematically accepted conceptions. Ely (2010) moves in this direction when he privileges the nonstandard thinking of a university student who begins to develop notions of the infinitely small similar to those of Leibniz. This noticing of robust and non-standard thinking would not have been possible if the researcher had not temporarily set aside standard mathematical results as a target for thinking. The infinitesimal became a playground for thinking, rather than a notion to be eventually critiqued because it is not consistent with standard real analysis.

The literature noted above leads us to ask the following questions: How should we think about infinity as an educational space? What opportunities does the context of infinity provide for mathematical thinking by students of mathematics? Our work with children and young adults will lead us to suggest a more radical position than Ely: that infinity is indeed a playground for legitimate thinking, regardless of the trajectory of that thinking.

How We Got Here

This research is based is an adaptation of experimental design research, (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Shavelson, Phillips, Towne, & Feurer, 2003) a focused form of action research. Its structure involves the design and honing of instructional resources and activities that others may use. However, its purpose as a form of educational research is to explore the qualities of student understandings as the development of instructional resources progresses (Lobato, 2003). In this case, the instruction deliberately and aggressively attempts to reorient students' approaches to learning mathematics toward the challenge of developing conceptual understandings rather than the stockpiling of additional procedures, and it uses challenging mathematical activities drawn from an academic study of the history of mathematics to accomplish its educational goals.

In the past, each of us have done independent teaching experiments in which students grappled with notions of the infinite (Author A, 2010; Author B, 2009, 2005, 1992). To extend the mathematics education community's understanding of how students construct infinity as a concept, we are subjecting our stockpile of educational activities to another cycle of redesign, implementation and evaluation. In doing so, we have looked again at the student data that our previous teaching experiments generated. Fundamentally, then, our research, still in process, has two intentions, represented by two questions:

1. What features of instructional activity enable students to grapple constructively with the difficult notion of infinity?
2. What characterizes 'better' understandings of infinity as a learned mathematical concept, as students progress toward a flexible, robust, and coherent conceptual understanding?

The first of these questions will be answered, in part, by the results of our design and redesign of instructional activities, complete with materials, presented (as they must always be considered) as works-in-progress.

Answering the second question has led us to interact with the criteria that mathematics communities use to determine the appropriateness of mathematical conceptions and pose some independent considerations appropriate for a post-Tylerian (Wallin, 2002; Wright, 2000), perhaps post-constructivist (Kieren, 2000; Steffe & Kieren, 1994) orientation to the development of conceptual understanding as a curricular intention.

The Instructional Design Elements

The infinity 'equipment' we have been designing for our mathematical 'playground' now constitutes a range of inquiry-oriented activities, inclusive of activity outlines, materials, and guidelines for conversations, all at varying stages along the design-experiment continuum of design, implement, evaluate, and redesign. Fundamentally, they each take literally the challenge in William Blake's ideal:

> To see a world in a grain of sand
> And a heaven in a wild flower
> Hold infinity in the palm of your hand
> And eternity in an hour. (c. 1803)

We ask ourselves, how can students hold infinity in the palm of their hands, shape it and test it? How can they 'see' the universe, eternity, or heaven, mathematically, and question what they see? Our design elements to date (none of which live up to the scale of Blake's invitation!), include:

a. exploring three times one third in a variety of active, tactile, and visual contexts, to ask whether "point nine repeating" compares with 1.
b. repeated halving and doubling activities as tactile engagements with $(2)^n$ and $(½)^n$: fractal cards, the ancestors paradox, folding a newspaper, the radical rose, the carrot patch.
c. grappling with $y = 64/n$, as n gets really large, really small, and really nearly zero
d. reconstructing the cognition of Archimedes: the poppy-seed universe; the perimeter and area of n-gons as n is doubled; the rationality of π;
e. 'Diminishing returns' activities: The bouncing ball; iterated folding activities; taxicab-geometry sequences approaching the hypotenuse.

To illustrate the kinds of instructional activity we are designing, this paper features two other pieces of 'equipment' from our infinity playground with which readers are likely quite familiar: Zeno's paradoxes and Cantor's cardinality of sets.

Zeno's paradoxes are an educational context that could trigger thinking about the profoundness of infinity (Chavez & Reys, 2002). We used the following version: In moving from A to B, a person must first arrive at the half way point. Subsequently, the person must pass the half way point of the remaining distance. Continuing this reasoning indefinitely, a person must pass an infinite number of halfway points before reaching B. But then how is it that a person can reach B, having to traverse an infinite number of distances in a finite time? The psychological difficulty of this paradox is that we can intuitively imagine traversing an infinite number of points whereas motion is continuous and not infinitely divisible (Fishbein, 2001). In our experiment, we asked grade 4 students to act out the paradox on a learning carpet, moving from one edge to the opposite edge, following the rule that we move in steps of half the remaining distance. Students were then asked to debate whether we could reach the opposite edge of the carpet.

In the second instructional activity to be shared, students are led to engage with the comparison in size of infinite sets. Cantor's notion of the cardinality of sets has at its core the one-to-one correspondence between elements of the sets being compared (Muir, 1961). At the heart of the challenge for students is recognizing the legitimacy of one-to-one mapping as a legitimate alternative to counting as a cardinal process, even when mapping doesn't enumerate a set. The instructional design challenge begins with the notion of putting infinite sets into the hands, eyes, and minds of learners.

The instructional design for the Cantor sets inquiry features number lines made with adding machine tape. One tape shows the first twenty natural numbers {1, 2, 3, …, 20}, written every ten cm, with the rest of the natural numbers represented by "….". Another tape shows the first twenty whole numbers {0, 1, 2, 3, … 19}, and, when juxtaposed with the first tape so that equal numbers are aligned, students agree that the whole numbers are larger than the naturals by 1. When the tape is shifted, however, so that they both start together (the zero in the whole numbers is aligned with the 1 in the naturals), they are not so sure. Further sets are posed for comparison with the naturals: the naturals larger than 10; the even naturals; the multiples of 7; the squares; the negative integers. As students come to generate incompatible ideas, such as that the set of even numbers has half the numbers as the set of natural numbers, but are the same size because they can be matched/mapped one to the other, the students resolution of the disequilibrium they experience depends of their mathematical thinking and communication skills, and the leadership of their teacher.

And the Students Played

Zeno's paradox did indeed trigger the expected psychological difficulty. On the learning carpet, we saw some students finishing the remaining small distance while other students tried to creep a little bit closer. Children also would reach out with an arm and state, "I am there." We continued to remind them of the rule for taking steps (half the remaining distance), and practice the process several times, so students had experiences trying to reach the other end of the carpet several times before the class debate. During the debate, two camps emerged, one arguing that the other end of the carpet could not be reached, while the other arguing that it could be reached. Based on an articulate student representative from each camp, we found that legitimate philosophical positions emerged, one that the journey could be completed based on the indivisibility of the smallest "things" in the universe; and the other that the journey cannot be completed based on an inductive informal mathematical argument.

We are not suggesting that if this context is recreated in every classroom, then these two legitimate philosophical positions will emerge. In fact, we were surprised by a grade 4 student using an indivisible atom to defend an intuitive notion that the journey can be completed. Friedlander (2009/2010) used a Zeno-like story of a child continually eating half of a remaining cake with gifted grade 5 students. Some of these students also used an "atom is indivisible" argument to conclude that there will eventually be a last bite that consumes the rest of the cake. Friedlander used Zeno-like stories as an educational context for children to informally explore their intuitive conceptions of infinity, where these intuitions are a starting point for moving toward taking-up accepted formal mathematical understandings of infinity in later grades. Our data suggests that these intuitions are in fact legitimated by the philosophical qualities of their argumentation. These qualities could not have been noticed, let alone triggered if the disposition of the teacher was not one of legitimating thinking, regardless of whether it would eventually converge on accepted truths.

Similarly, we were able to lead students to engage with the cardinality of infinite sets effectively. Students perceived the entry points to the inquiry as accessible and inviting. They were able to arrive at cognitive positions in which two apparently irreconcilable answers both appeared credible. They were able to generate and explore potential resolutions of their disequilibrium. To some extent they were able to see beyond the limitations of their newly generated understandings toward the frontiers of mathematics that Cantor explored. Some students felt it was a matter of perception: "it depends on how you look at it." Others felt that there had to be something wrong, because "they can't both be right. There's only one right answer, in math." After discussing the examples they shared, the students expected to be told the resolution to this riddle. We did not satisfy their expectation, and so they left the infinity playground having been happily perplexed by their experiences but disappointed to have no resolution.

What We are Learning

We are discovering that it is not impossible to enable students to construct the infinite and infinitesimals with their hands, their eyes, and their minds. Like children on playground equipment, students have explored the possibilities of the equipment we provide and the activities we recommend, and have been intrigued by the dissonance that their inquiries generate. We have found that the design of the playground equipment matters, and we are fine-tuning our design through each iteration we plan. For instance, in our last enactment of infinity, students determined the halfway point between their position and their goal by visual estimation. We are considering having them use string to measure the distance without numbers, and half that distance by folding the string. How will the increased accuracy affect their conceptions of what happens as the distances get very small? We look forward to finding out. At the same time, we are wondering what might be gained by having students look at diminishing sequences in more than one context concurrently—would students recognize similarities and differences between their Zeno experiences and an experience determining the distance traveled by a dropped rubber ball (Vinogradova & Blaine, 2010)?

Similarly, with the Cantor sets, we continue to fine-tune. We would like to find out the effects on students' generalization across cases if groups each get to pioneer a different set comparison by building the paper-tape number lines themselves for follow-up comparisons. If our group explores comparisons of the multiples of five to the natural numbers, and another group compares the powers of two to the even numbers, will students appreciate the experiences and interpretations from other groups in comparison to their own? In our design research, activity design is a form of playground for us as educators, and we're having fun.

Yet there are bigger ideas emerging from our inquiry. We began by considering what students could learn about infinity. We have drifted, not accidentally, toward discussing what students might experience by engaging with infinity. Through interacting with the thinking by students, we have come to perceive it to be legitimate and valuable in and of itself, regardless of the consistency of the students' conclusions with current mathematical resolutions regarding the paradoxes of infinity. The thinking of students described above is a potent reminder to us that thinking is a goal that should trump all other considerations, including the current canons of mathematics. Such a conclusion leads to curricular and research recommendations.

In terms of curriculum, that educators would want mathematical learners to eventually take-up – understand and accept – current truths in mathematics cannot eclipse our desire to have students engage in thinking as a process. We find ourselves shifting our attention away from content or outcomes respectful of the continually evolving mathematical canon concerning infinity. As Ely (2010) suggests, infinity as a playground can provide students with opportunities to exercise their thinking processes, increasing their capacity to learn content.

Further, we believe that a rich line of educational research is available by generating activities where students play with infinity. As such, our future work will continue to develop contexts for exploring the infinity playground. For example, what qualities of thinking will arise when students try to make sense of zero divided by zero ("0/0=?"), where the educational context does not privilege in any way the current mathematical thinking that 0/0 is indeterminate? Considering 0/n for $n \neq 0$ suggests 0/0 = 0. Considering n/n for $n \neq 0$ suggests that 0/0 = 1. Considering 1/n as n approaches 0 suggests 0/0 = infinity. Considering 1/0 when entered into a calculator suggests that 0/0 is out of bounds, sinful in some way (Beskwick, Richman, 1999). We suggest that *educationally* it is less relevant how much mathematics content students remember about this mathematics, or whether their conclusions map onto Dubinsky's notions of 'actual' infinity (Mamalo & Zazkis, 2008). *Educationally*, what matters more is how, and how much, and how well, students develop as mathematical thinkers as they engage with each piece of equipment on the mathematical playground. And we believe that, in terms of mathematics education, the pedagogy of infinity may be remarkable 'playground equipment' for research about mathematical cognition, the growth of mathematical understandings through experience.

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Section 2: Educational Technology

EDUCATIONAL DESIGN OF A SNAKE GAME FOR BASIC MATHEMATICAL OPERATIONS WITH A DIFFERENT APPROACH

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ABSTRACT: Today with the rapid developments in technology computers and computer related environments become a vital part of life. Such positive changes in information technology can affect all aspects of education positively including both content and learning process. In particular, computer games that make education fun are positively affected by this interaction, making computer games as one of the issues that should be emphasized in education and training. Games have a very important role in the development process of children. Therefore, games and educational tools are being developed to accelerate children's education and intelligence development. Educational games create opportunities for children to learn new things as well as increasing their mental abilities, and ease to understanding of boring subjects and courses. In this work, a snake game has been developed. C# programming language has been used and an educational game combining snake game and mathematical operations which have not been done before designed. A digital game that can teach basic mathematical operations easily, fast and a fun way to students mostly in primary education level has been designed. With the designed game improving player’s skills in basic mathematical operations are aimed.

Keywords: digital games, mathematical operations with games, educational games, snake game

INTRODUCTION

Today, as a result of rapid development of technology, computers have become an indispensable part of our lives. With the growth of computer technology, computer games become one of the most popular part of this technology. As an entertainment means computer games become more interesting increasingly and more preferable than other media, such as cinema or TV, for people in every age (Korkusuz & Karamete, 2013). In 1980’s while children were spending approximately 4 hours on gaming at homes or Atari saloons, nowadays it’s 5.5 hours with girls and nearly 13 hours with boys who are primary and secondary education students (Christakis, et al., 2004; Bayırtepe & Tüzün, 2007). Additionally, today, while there are 1 billion gamers around the World, Turkey has 20 million gamers and 20 billion dollars market share. Because of this digital gaming market is growing rapidly in Turkey (Karahisar, 2013). Today only World of Warcraft has 10 million subscribers and in the near future it is expected MMOG (Massively Multiplayer Online Games) market share will be 15 billion dollars (Bostan & Tıngöy, 2015). The gamers who have played “Call of Duty Black Ops” game have spent over 600 million hours in game in the first month following the release (Korkusuz ve Karamete, 2013).

Today with the global advances and changes in the World another notion we hear with the education notion is educational games (Çoban, Yıldırım and Göktaş, 2011). With the help of educational games, gamers can consolidate previous knowledge and learn new things while having fun (Bayırtepe & Tüzün, 2007; Erkan, 2012). Therefore, games have significant value for education and intelligence development for children and teens. Another advantage of educational games is that they are easy to learn. The student learns the game through trial-and-error.

When age distribution is considered, teens and children form the majority of gamers. Usage of games in education is an important topic that needs to be focused considering the time children spend on games. Presky, William and Stock has found out that students who use educational games are %30 more successful than the control group students in a research that includes 400 schools (as cited in Korkusuz & Karamete, 2013). This research shows the necessity of using games for the purpose of education. For this purpose, an educational snake game has been developed for students starting from the second year of elementary school and enthusiasts of the snake game.

In this paper, a snake game for basic mathematical operations designed with the usage of C# programming language. Gamer requires finding the wanted number by using the given operations and numbers. There is a time limit for that. The player is scored according to usage of time and the difficulty level of the problem. Additionally, with the random bonuses (hard), it is granted that gamers have more points and lives. In this way, improving player's skills in mathematical operations is aimed.

Game

There are lots of definitions of 'game'. Game is an activity that people do willingly and happily in an appropriate time and place out of their responsibilities that supports their mental and physical skills. Games are things that people do willingly and things that people obligated to do are not games (Erkan, 2012; Hazar, 1996). Fundamental things that a game must consist are:

1. Aim
2. Finish factors and save
3. Realistic story
4. Playability
5. Replay
6. Balance
7. Prize
8. Environment

Computer Games

Nowadays, even though the word "game" generally refers to digital games, digital games have different features. Environments similar to real places are presented to gamers with computer games. Computer games are designed so that it includes competition, rules and a goal that motivates the gamer (Erkan, 2012; Pagulayan, et al., 2003).

Parallel to advances in computer science and its widespread usage, computer games have shown a continuous growth. Features in games have increased with the developments of high CPU power and graphic features. Also growing population that use computers have increased and people who play games take a place in gaming sector (Korkusuz & Karamete, 2013).

Educational Games

Educational games contain entertaining and motivating features like in common games. Educational games are a fun thing to do but also have features that teaches new things and reinforces previous knowledge. Therefore, to contribute to learning computer games can be used as a complementary tool. In educational game design, usage of imagination and ability to synthesise, determination of what to teach and how much student learned the taught concepts and effective usage of time and situations should be taken into account (Çankaya & Karamete, 2008). Educational computer games, when designed suitable for students' own levels, considering their interests and needs and suitable for individual study provide more effective and permanent learning. It is difficult to find the visual and auditory elements contained in the virtual game environments in books or movies. Because computer games, unlike to books and movies, grant interactions and allow users to trial and error (Erkan, 2012). Also they help students to improve their skills and learn new information around the patterns of the subject the game developed around.

Game Programming

Game programming is software developing department of video games. Game programming that requires significant work on software engineering is a combination of graphic design, entity system, user interface, physics engine, input handler, artificial intelligence component, game logic, level and sound systems as a whole (Türkmen, Yalın and Tekir, 2015).

Game programming due to its multidimensional and complex structures shows differences from other programming techniques. In lots of programs other than games, changes can be made after coding started and can be implemented to program easily. But in game programming, all rules should be determined and examined before coding the program and then coding part should start after. In game programming, any rule change requires that nearly whole program should be written again (Erkan, 2012).

In this project, C# programming language has been used. C#.NET is a Microsoft's robust, component-based programming language. The people who have experience with C, C++ or Java can learn C# easily.

Good-looking and timesaving projects can be made with Microsoft Visual Studio's rich tools. C# programming language is a new generation programming language which Microsoft developed. It is a programming language developed for Microsoft's .NET environment (Yıldırım, 2012).

APPLICATION

With this project, a game that improves student's skills with mathematical operations has been developed. There are 3 levels for different education levels. This way, extensive player base has been intended. Figure 1 shows the level choosing page.

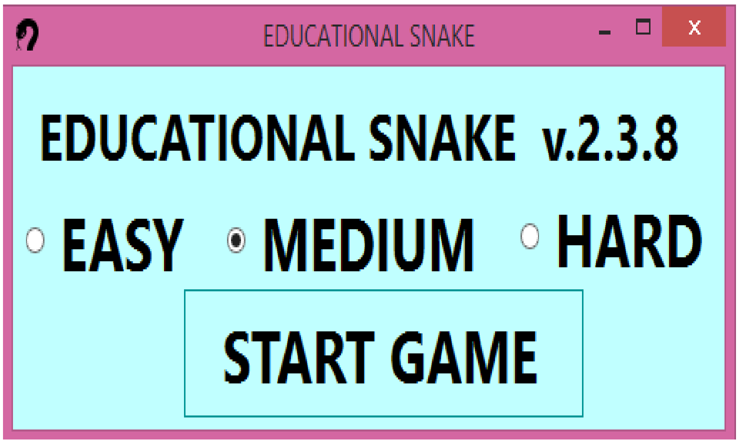

Figure 1. Level Screen

In all levels, game consists of 7 parts and each part includes 3 questions. The difficulty levels of questions change by levels and parts. The difficulty levels increase as the game progress. After choosing the level, player comes to the game screen that is shown by Figure 2.

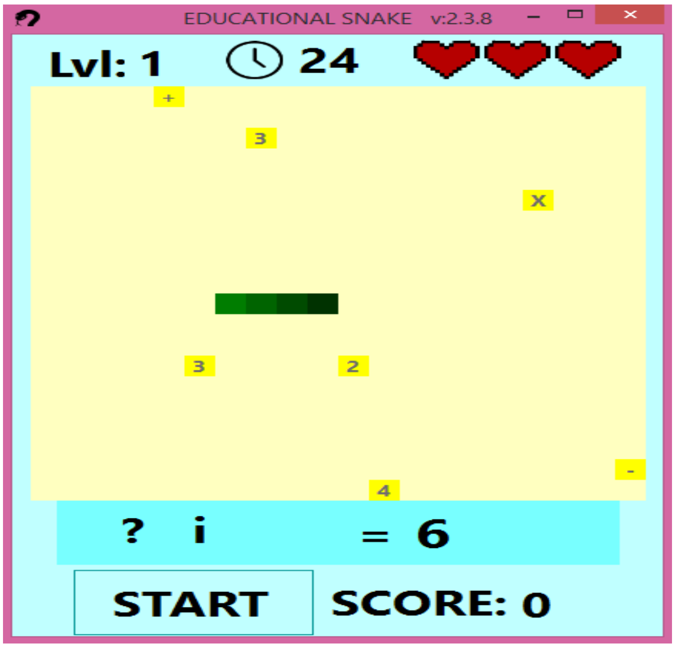

Figure 2. Game Screen

Appropriate questions will be asked to player according to chosen level. Three life points are given to players as shown in Figure 2. There is a time limit for the question. This way, getting rid of the slowness of the game and improving player's fast thinking abilities have been intended.

As soon as the game opens, time limit starts to decrease. Player loses one life point when the time limit ends or player gives a wrong answer.

Player needs to pick a number than an operation symbol than another number to answer the question. If the answer to the question is right, game automatically provides player with a more difficult question and asks for answer. If the player picks two numbers in a row, game will not accept the pick and will give an error that the player should choose an operation symbol. If the player picks a wrong operation symbol, player can pick another symbol before the time limit ends. The game accepts the last picked operation before picking the second number. In this way, the choice of taking different routes to the answer has given to the player.

In some parts, players may be asked random bonus questions. Bonus questions appear as a hearth symbol that flashes. If the player picks the random question, s/he will encounter with a hard question. If the player answers the bonus question truly, s/he will gain more points and an extra life point. In figure 3, the screen that bonus question appears has been given.

Figure 3. Bonus Questions

With bonus questions player can restore lost points so that his/her motivation increases. Also increasing the player’s confidence has been aimed with the bonus questions. Player who lost all his/her life points sees the Score Screen as shown in Figure 4 and asked to enter his/her name. This way player’s name and score can be stored.

Figure 4. Score Screen

The player’s scores are saved in database according to chosen level categories and player can see his/her own score and highest scores. Score screen is shown in Figure 5.

Figure 5. Score Screen

Score system will increase player's motivation and player will show more effort to reach high scores.

CONCLUSIONS

Educating basic mathematical operations was made more interesting with this study. In this respect, this study will provide contributions to player's information gain, consolidation of existing information and children's intelligence development. Also, players will entertain themselves while improving their abilities with mathematical operations and learn effective usage of time.

While the player is playing the snake game, the player is also trying to obtain the target number using the numbers and actions displayed on the screen. Thus, educational snake game design will provide players with physical and mental stimulation.

With educational computer games, students learn more easily as they learn with fun and the topics taught become more permanent in memory. This will leave a more positive conception instead of the general negative conception in the majority of students against mathematics lesson. With the developed game, individual learning environments have been created for students with different learning levels. Each student will be able to play the game in accordance to his/her own level and will be able to provide feedback about the subjects taught. According to the feedbacks, teachers may have knowledge about student's level of learning. Thus, learning with fun, consolidating previous knowledge and getting feedback will be done at the same time.

Studies in this field are suitable ways to provide more effective and efficient learning in combination of education, entertainment and motivation.

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A LITERATURE REVIEW: IPAD TECHNOLOGY IN THE MATHEMATICS AND SCIENCE CLASSROOMS

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ABSTRACT: Science, technology, engineering, and mathematics (STEM) education has become an emphasized component of PK-12 education in the United States. The US is struggling to produce enough science, mathematics, and technology experts to meet its national and global needs, and the mean scores of science and mathematics students are not meeting the expected levels desired by our leaders (Hossain & Robinson, 2011). In an effort to improve achievement scores in mathematics and science, school districts must consider many components that can contribute to the development of a classroom where students are engaged and growing academically. Technology for student use is a popular avenue for school districts to pursue in their goal to attain higher achievement. Research in computer technology has shown positive effects in academic achievement with the largest effects found in constructivist classrooms. Questions remain as to whether that translates to the use of iPads and other tablet devices being successful in raising the academic achievement of students in the mathematics and science classrooms.

Keywords: one-to-one, iPad, mathematics, science

INTRODUCTION

iPad Technology in the Mathematics and Science Classrooms

Science, technology, engineering, and mathematics (STEM) education has become an emphasized component of PK-12 education in the United States. The US is struggling to produce enough science, mathematics, and technology experts to meet its national and global needs, and the mean scores of science and mathematics students are not meeting the expected levels desired by our leaders (Hossain & Robinson, 2011). According to Cavanagh (2008), the Program for International Student Assessment (PISA, 2006) stated 15-year-old US students ranked 24th on the mathematics test and 17th on the science test compared to 29 other industrialized countries (as cited in Hossain & Robinson, 2011, p.2). The US's once acquired leadership status in mathematics and science education has fallen behind many other countries. Ramirez (2008) stated "The fact that some less developed countries now perform better in math and science achievement than the US is seen by many US educators, business leaders and politicians as a crisis" (as cited in Hossain & Robinson, 2011, p.2).

In an effort to improve achievement scores in mathematics and science, school districts must consider many components that can contribute to the development of a classroom where students are engaged and growing academically. Technology for student use is a popular avenue for school districts to pursue in their goal to attain higher achievement. It has become a much-studied research topic in the last few decades as school districts commit to spending their precious resources of time and money for technology integration in the classroom. Determining the best plan of implementation falls on all education partners including administrators and teachers. They must take many issues into consideration such as affordability, infrastructure, and best practices when deciding what technologies should be incorporated into the classroom.

The U.S. Department of Education, the National Council of Teachers of Mathematics (NCTM), the National Science Teachers Association (NSTA), and the International Society of Technology in Education (ISTE) have supported technology integration in the PK-12 classroom as a means to create more effective mathematics and science instruction for US students. The U.S. Department of Education (2010) contributed to this charge by stating in its National Education Technology Plan "technology is the core of virtually every aspect of our daily lives and work, and we must leverage it to provide engaging and powerful learning experiences and content, as well as resources and assessments that measure student achievement in more complete, authentic, and meaningful ways" (p. ix).

National Council of Teachers of Mathematics

Mathematics, Science, and Technology leadership organizations are promoting the use of modern technologies to enhance instruction. The NCTM (2011) released an organizational position stating we must provide regular access to technology in order to develop sense making, reasoning, problem solving, and communication in our students. Teachers who can effectively use technology to help students with their understanding, to increase their interest in the subject, and to raise mathematics proficiency will be successful in providing greater access to mathematics for every student. The Common Core State Standards for Mathematics (CCSSM, 2010) also encourages the use of technology in its fifth standard for mathematical practice: use appropriate tools strategically. It states mathematically proficient students will use available tools including calculators, spreadsheets, statistical packages, and dynamic geometry software to solve mathematical problems. Mathematics proficiency opens the door for a number of career choices in the STEM fields empowering our students for their future.

National Science Teachers Association

The NSTA, through its Next Generation Science Standards (NGSS, 2013), also encourages the use of technology for the role it plays in the learning of science by recognizing that new technologies have given our scientists new capabilities for studying the natural world. The advances in technology have also provided more precise ways to record, manage, and analyze data as students conduct investigations during the learning process. The NGSS framework states, "engineering and technology provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge to the solution of practical problems… By integrating technology and engineering into the science curriculum, teachers can empower their students to use what they learn in their everyday lives" (NGSS, Appendix A, p.5).

International Society of Technology in Education

ISTE (2013) developed the widely recognized standards for learning, teaching, and leading with technology. Through sets of standards designed for students, teachers, administrators, coaches, and computer science educators, ISTE has provided schools with a set of best practices for technology use designed to improve higher-order thinking skills, prepare students for the global job market, design student-centered, project-based and online learning environments, guide schools in creating digital places of learning, and inspire models for students to encourage working, collaborating and decision making.

With the support of the national groups and an abundance of technology appearing in schools, it is imperative teachers learn effective ways to incorporate technology into their classrooms to increase academic achievement. The National Education Technology Plan (US Department of Education, 2010) calls for teachers to use technology to create engaging and empowering learning experiences for their students that are designed to meet the individual needs and the prior knowledge of the learner.

The Choice of iPads for the Classroom

Mobile devices, such as the iPad and other tablet-based devices, are some of the latest technology schools are looking toward for assistance in the teaching of the CCSSM and NGSS standards. There has been a substantial amount of research on computer technology in the areas of mathematics and science showing the benefits of its implementation in the classroom (Bayraktar, 2002; Li & Ma, 2010). However, according to Fisher, Lucas, and Galstyan (2013), "There is very little research involving the direct observation of the usage of iPads in the classroom" (p.166). Most of the iPad-focused research involves analyzing students' and teachers' perceptions of the benefits of iPads rather than measuring its effects on academic achievement. In order for school systems to justify the expense of incorporating mobile devices, such as the iPad, into their instruction, research needs to be conducted to determine the effect, if any, on students' learning.

The review of the literature for the use of iPads in the classroom centered on the following topics:

1. Technology in a constructivist learning environment (CLE)
2. Constructivist-oriented Technological Pedagogical Content Knowledge
3. Computer technology in the mathematics and science classroom
4. iPads in the mathematics and science classroom
5. iPads in a one-to-one environment
6. Laptops in a one-to-one environment

Constructivism and the Constructivist Learning Environment

Ertmer and Newby (1993) stated Constructivism sees knowledge as something an individual creates from his experiences. The learner and the environment play a part in the construction of knowledge through their interactions with each other, and knowledge is constantly evolving as the learner experiences more of the world. Learning must take place in a real world setting where students can relate prior knowledge to the task at hand. Strategies most appropriate for a constructivist-learning environment are providing tasks mirroring real world situations, modeling and coaching throughout the process, collaborative learning, discussions, debates, and reflection during and after the task. Constructivist teachers emphasize the context in which the learning occurs, encourage learners to actively use their prior knowledge, present information in multiple ways, and support using problem-solving skills. By analyzing different ways of representing a problem, they can design experiences that are authentic and relevant to the learner's world.

From Constructivism has come the instructional design of constructivist-learning environments (CLE). A CLE can be defined as "a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities" (Wilson, 1996, p.5). Jonassen, Peck, & Wilson, (1999) add these environments provide students with the opportunities to "explore, experiment, construct, converse, and reflect on what they are doing so that they learn from their experiences" (as cited in Wang, Teo, & Woo, 2009, p.81). This leads to a more student-centered and collaborative learning environment. Participating in this environment allows students to deepen their understanding of content through the use of resources and sharing of knowledge (Kong, 2011).

Technology can aid in the construction of a CLE by providing current information not available in textbooks giving an authenticity to the lessons. The use of online resources can facilitate "the learner's journey of discovery and acquisition of new knowledge. Communication resources such as discussion boards enable learners to participate in collaborative learning with other students and with educators" (Sultan, Woods, & Koo, 2011, p.151). Fosnot (1996) stated students acquire knowledge by physically constructing it through active learning. Providing technology-based CLE's allows students to participate in varying activities and engage in meaningful conversations with others (Jonassen & Rohrer-Murphy, 1999).

Teaching in a digital classroom allows teachers to promote the tenets of constructivism. The use of mobile devices are removing the constraints of time and space from the learning process and instead providing opportunities for students to communicate, collaborate in and out of the classroom, and access information freely (Wong 2012). In the constructivist classroom, assessments can range from self-report measures, classroom observations, and varying analyses of student performance data. One-to-one technology can afford teachers the opportunities to incorporate many different forms of assessments (Sultan et al., 2011).

By definition, a traditional approach is teacher-oriented with instruction focused more on lecture, whole group lessons, and mastery of facts and skills. The teacher solves problems for the class and students' differences are only addressed if there is a problem. Typically, a single assessment for all students is used at the end of instructional units (Ornstein, Lasley, & Mindes, 2005). In contrast, a constructivist approach is student-oriented with activities designed to encourage active learning. Assessments are different from one single test at the end of a unit. Instead they can be formatted as project work, portfolios, self-assessments, and performance evaluations (Ayaz and Sekerci, 2015). iPads provide digital tools to enhance this type of assessment.

Hoffman (2010) stated that as we shift to a student-centered learning environment, we are providing opportunities for students to learn 21st century skills of inquiry, critical thinking, communication and collaboration. Technology can assist in this shift. However, it is essential schools are using technology to its fullest potential.

The challenge for teachers is to take the recommendations of the national organizations and the available technology and use them to provide students with a constructivist-learning environment that encourages participation both individually and collaboratively, addresses prior knowledge of the student, allows for the creation of activities that continuously spiral back to past learning, and provides opportunities to apply learning to real life scenarios.

Teachers' Perceptions of C-TPACK

With a shift to more technology-infused CLE's, it is important teachers know how to successfully integrate the devices into instruction. A constructivist classroom has shown to be effective in increasing achievement (Ayaz & Sekerci, 2015). However, teachers must feel comfortable with and prepared to use the technology in order to create a successful technology-infused learning environment for their students. Koh, Chai, and Tsai (2014) conducted a study to determine teachers' perceptions of their constructivist-oriented technological pedagogical content knowledge (C-TPACK). C-TPACK refers to a teachers' knowledge of using technology with appropriate teaching methods for their content area to implement constructivist instruction.

Koh's et al. (2014) research study included 354 teachers, 54% at the elementary level and the rest at the secondary or junior college level. The average teaching experience was 8.83 years and the average age was 34.93 years. The questions addressed were:

1. What are Singapore practicing teachers' constructivist-oriented TPACK perceptions?
2. How do teacher demographics (age, gender, teaching experience, and teaching level) and TPACK constructs (C-TK, C-PK, CK, C-PCK, TCK, and C-TPK) predict practicing teachers' constructivist-oriented TPACK (C-TPACK)? (p.187)

In order to create the survey, Koh, et.al., examined Jonassen, Howland, Marra, and Crismond's (2008) principles that relate to an information and communications technology (ICT)- supported constructivist learning environment. The five principles included students actively manipulating objects and observing results, reflecting and articulating their personal understandings of their observations, engaging in authentic tasks based on real world problems, intentionally setting goals for learning and planning problem-solving processes, and collaborating to problem-solve within their classroom community. Technology can serve as a tool to support these principles to encourage our students to be engagers and facilitators of thinking.

Koh et al. (2014) used these five dimensions and the seven-construct TPACK framework developed by Mishra and Koehler (2006) to assist in the creation of their teacher survey. The seven constructs included the following:

1. Technological knowledge (TK) – knowledge of technology tools
2. Pedagogical knowledge (PK) - knowledge of teaching methods
3. Content knowledge (CK) – knowledge of subject matter
4. Technological pedagogical knowledge (TPK) - knowledge of using technology to implement teaching methods
5. Technological content knowledge (TCK) – knowledge of subject matter presentation with technology
6. Pedagogical content knowledge (PCK) – knowledge of teaching methods with respect to subject matter content
7. Technological pedagogical content knowledge (TPACK) - knowledge of using technology to implement constructivist-teaching methods for different types of subject matter content

The researchers then added the constructivist-oriented component to the seven constructs to create C-TK, C-PK, C-CK, C-TPK, C-TCK, C-PCK, and C-TPACK to address the responses of the survey.

Koh's et al. (2014) survey collected teachers' reported abilities of incorporating technology into a constructivist-learning environment. It was designed on a Likert scale where 1- strongly disagree, 2 – disagree, 3- slightly disagree, 4 – neither agree nor disagree, 5 – slightly agree, 6 – agree, 7 – strongly agree. They found teachers rated themselves as highly confident of their content knowledge (CK) with a mean of 5.84, their ability to provide constructivist instruction (C-PK) with a mean of 5.56, and their ability to provide constructivist instruction specific to their content area (C-PCK) with a mean of 5.43. However, when the survey added technology into the equation, the confidence level dropped. Teachers rated their ability to use technology tools to create a constructivist instruction (C-TK) with a mean of 5.17, their use of technology to teach their content area (TCK) with a mean of 5.20, their use of technology in their teaching to create constructivist instruction (C-TPK) with a mean of 5.20, and their knowledge of technology to create constructivist instruction in their content area (C-TPACK) with a mean of 4.86. The teachers' surveys showed they were confident in implementing constructivist-oriented instruction but revealed their struggles were in the areas of ICT-driven constructivist-oriented instruction.

After reviewing the responses to the survey in regards to their confidence in the seven constructs, Koh et al. (2014) then turned to analyzing the results by teacher characteristics. They found a small negative correlation between age with TPACK constructs and teaching experience with TPACK constructs. They also found males rated themselves higher (small effect size) in constructs that had technology as a component. In addition, primary teachers rated themselves lower (small effect size) in the construct of C-TPACK than secondary and junior college teachers.

Some possible explanations of Koh's et al. (2014) finding are that more experienced teachers, who had a lower perceived C-TPACK, are more influenced by the exam driven school system that has traditionally been focused on the dissemination of knowledge and facts rather than a constructivist approach. Also, primary teachers, who perceived themselves as lower than other participants in C-TPACK, may be at a disadvantage solely due to the fact they teach multiple subjects at the elementary level. Secondary and junior college teachers typically focus on only one content area and thus may be more confident with C-TPACK.

Koh et al. (2014) concluded that this study could give insight into how school districts could provide professional development to assist teachers with technology implementation in the classroom. First, professional development needs to go beyond teaching constructivist instruction in general to more specific training of how to address ICT in a constructivist context. Greenhow, Dexter, and Hughes (2008) stated teachers focus their technology integration on how to represent content. However, Windschitl (2002) stressed teachers must learn how to instead focus on facilitating student learning through authentic problem-based tasks and creating opportunities for classroom discourse. Teachers need to have a strong C-TPACK in order to create a technology-infused constructivist-learning environment.

Constructivism and Technology in the Classroom

Overbay, Patterson, Vasu, and Grable (2010) found teachers who leaned toward a constructivist approach in the classroom and thought the technology could be used as a tool in a student-centered environment were more likely to report using technology. "With the rapidly changing landscape of the K-12 classroom, asking questions about the relationship between constructivist practice and the use of classroom technologies seems more important than ever" (p.104). As a result, teachers that adhere to the constructivist theory would use technology to engage students and to encourage them to find meaning in the material versus memorization of facts. The tools would be used for knowledge construction rather than drill and practice focused on skills.

Overbay et al. (2010) researched the IMPACT model of technology integration, designed to promote student-centered learning, being used in North Carolina schools. This model was designed to provide teachers and media and technology personnel the opportunity to collaborate as they developed a student-centered environment focused on 21st century learning. The project examined the relationship between teachers' level of constructivism and their reported use of technology in the classroom. One of the research questions was "What was the relationship among individual-level variables (e.g. sex, years of experience, and subject taught) and technology use, and do they interact significantly with level of constructivism in predicting technology use" (p.106)? Overbay et al. used The Activities of Instruction (AOI) survey to measure the amount of constructivist practices that were occurring in the North Carolina schools. This survey was developed to consider constructivist practices when describing classroom activities of teachers at different grade levels.

Overbay et al. (2010) found teachers' reported level of constructivist practice had a significant positive association with their level of reported technology use. After studying the other variables, they found the best predictor of teachers' reported technology use was the level of constructivism. They interpreted this to state, "teachers who use constructivist activities are also willing to incorporate technology into routine student-centered activities" (p.116). As school districts strive to find the most effective ways to implement technology, training teachers on how to create a constructivist- learning environment may result in classrooms that are actively incorporating technology into lessons.

Computer Technology in the Mathematics and Science Classroom

Mobile devices, specifically the iPad and other tablet-style devices, are the most recent in a long line of technology tools made available for classroom implementation over the past decades. Computer technology (CT) and computer assisted instruction (CAI) have been a part of the learning environment for quite some time and is only growing. By 2001, US public schools housed more than ten million computers and 87% of classrooms offered Internet access (Hernandez-Ramos, 2005, as cited in Holden, Ozok, & Rada, 2008). Now, years later, the issue is no longer access to technology but how can we use it to promote student learning and achievement (Holden et al., 2008). Is mobile technology a viable option for increasing learning and achievement? Past studies on computer technology seem to support answering that question positively (Bayraktar, 2002; Li & Ma, 2010).

The use of computer technology in education has been researched for the last few decades, and numerous studies and meta-analyses have been completed on the effects of CAI and CT use on achievement in the mathematics and science classrooms (Bayraktar, 2002; Li & Ma, 2010).

Computer Technology in the Mathematics Classroom

Li and Ma (2010) conducted a meta-analysis of the effects of computer technology on K-12 students' mathematics learning. The research encompassed 46 studies involving 36,793 learners. This meta-analysis included studies providing research findings on the numerous implementations of computer technology now being used in the classroom.

The research gleaned from the 46 primary studies showed an overall small, positive effect (0.28) of CT on mathematics achievement. Of the 85 effect sizes found, only seven showed a negative effect on mathematics achievement. Li and Ma (2010) sorted the technology use into four types- tutorial, communication media, exploratory environment, and tools. The findings showed the types of technology use had no effect on mathematics achievement of students. However, the meta-analysis found large effects with certain teaching styles. When analyzing the data, they categorized the studies into two pedagogical approaches- traditional and constructivist teaching. To make the classification, they defined a traditional style as one that is teacher-centered with whole-class instruction whereas a constructivist style is student-centered with discovery-based and problem-based learning, and situated cognition based on constructivism. They found there was a large effect with CT use in a constructivist environment rather than a traditional one (1.00). "When used in settings where teachers practiced constructivist approach to teaching, technology had much stronger effects on mathematics achievement than settings where teachers practiced a traditional approach to teaching" (p.228).

In conclusion, Li and Ma (2010) found CT had positive effects on mathematics achievement when analyzing 46 different studies. In addition, they found one of the largest positive effects (1.00) came when teachers used a constructivist approach, by adding techniques such as inquiry-based and problem-based instruction when implementing technology in the classroom.

Computer-Assisted Instruction in the Science Classroom

Bayraktar (2002) conducted a meta-analysis on the effectiveness of computer-assisted instruction (CAI) on student achievement in the secondary and college science classroom by comparing CAI instruction with traditional instruction. Computer-assisted instruction is the use of computers in the classrooms to aid in the teaching and learning process. The purpose of the analysis was to determine the overall effectiveness of CAI in physics, chemistry, biology, general science, and physical sciences.

After including 42 studies that produced 108 effect sizes, Bayraktar (2002) first examined the overall effects of CAI on achievement in science. Of the 108 effect sizes, seventy of the effects were positive for the CAI group being more effective, 38 were negative meaning the traditional instruction was found more effective, and one study showed no difference.

Bayraktar (2002) next analyzed the different CAI implementations and found the most effective use of CAI was simulations and the second most effective was tutorial. Using CAI for drill and practice in the science class actually had a negative effect on achievement. Other implementations that were found more effective were software developed by the experimenter/teacher rather than commercial software and using the computers as a supplement to instruction rather than a replacement for regular instruction. There was no difference in effect size when examining the school level, and CAI was most effective when the duration of use was four weeks or less. Overall, Bayraktar (2002) determined the best implementations for CAI were to use it as a supplement to traditional instruction.

Mobile Devices

The issue that now arises is to determine if the success of computer technology on raising achievement has translated to success of mobile devices. Within the classroom, there has been a move in the past few years from computer technology to mobile devices, including iPads and Android tablets. According to Kiger, Herro, and Prunty (2012), as these devices become more prevalent, schools are using them to improve student engagement, collaboration, communication among peers and teachers, and to move learning past the walls of the classrooms. For instance, students are using them on field trips to enhance learning outside of the school building. These devices are a cheaper option to computers and provide teachers a viable way to enhance learning. However, this movement should be approached with caution. Melhuish & Falloon (2010) warn the device should not become the focus in this situation. Instead, "our focus must remain on the way mobile learning can be integrated into effective, evidence-driven, innovative practices, so that the learner is empowered and enriched by the learning experience" (p.13). The researchers go on to state five benefits mobile devices can bring to the classroom. Portability of the device allows students the ability to learn beyond the school desk. The devices are affordable allowing for a larger number of users. They also allow for situated learning opportunities that promote collaboration with others enhanced by the use of cloud-based computing. The ease of connectivity allows participants to interact with others. Finally, the mobile devices offer the ability to individualize a learner's experience.

Melhuish and Falloon (2010) specifically speak of the mobile device, the iPad, and its potential uses in the classroom. When revisiting the five benefits, the iPad is not only portable but has many of the functions of a computer without the costs of a computer that has the same computing power. The iPad's functionality also allows for a constructivist-learning environment as it promotes collaboration and can provide authentic tasks for students to explore. Its connectivity feature allows students to communicate synchronously or asynchronously in online learning communities. Finally, teachers are able to use the multiple functions, such as the plethora of apps; to create individualized learning opportunities for students.

The search for apps to use in the classroom can be overwhelming to teachers. According to Larkin (2014), although there are many apps available, teachers must determine which are of high quality and will promote understanding of the content rather than essentially being flash cards in a digital format. The information given in the app store is often not enough to make those decisions resulting in frustration of teachers with locating appropriate technological tools for instruction. In the area of science, the iPad apps can provide an experience student cannot receive from traditional resources. For instance, in the area of life science, there are many apps that allow students to examine the brain and cells by rotating and zooming in on key components to create a better understanding of the workings of the human body than still pictures in a textbook can provide (TCEA, 2016). Beyond apps, there are other technological resources for teachers to use in the classroom with the iPads. Hohenwarter and Preiner (2007) discussed Geogebra, a dynamic geometry software, which allows students to view concepts through two representations, graphically and algebraically, to help develop a deeper understanding of the mathematics being studied. This program is available for use on the iPad giving students a virtual way to explore mathematics.

As the push for mobile devices continues, schools must ensure the use of the iPad is based on sound research-based practices. However, limited research is available to show the effects of this mobile device on student achievement. The following address some of the studies involving the iPads in educational settings.

iPad Use in a University Setting- Mathematics Classroom

As mentioned earlier, Fisher et al. (2013) noticed a deficiency in research that addressed the usage of iPads in the classroom. As a result of this, the researchers completed a project in a university setting by studying the use of the iPads versus laptops in a business calculus classroom. They based their research on Vygotsky who “recognizes that the process of learning is inherently social and our interaction with others is central to our development as a learner” (p.167). They also relied on activity theory when collecting data by focusing on collaborative learning rather than individual learning. They looked at how the iPads were being used as students interacted in groups. Data was collected through observations, focus groups, and surveys. Through coding of the observations, they found there were three tiers of how the technology was used: multi-use, multi-view, and single-use. Multi-use involved multiple students using one device to complete activities. Multi-view involved one student sharing his work on the iPad with other students. In the case of single-use, the students discussed their work on the iPad but did not show the evidence to others. Through the surveys and focus groups, Fisher et.al. determined how students were using the technology during the instructional unit.

Fisher et al., (2013) found through the observations that students with iPads incorporated them in almost all interactions with other students whereas the laptops were only brought into this type of learning environment approximately half the time. The iPad group was more willing to share screens and look at each other’s devices during the learning. Another difference found was 7.5% of the time the laptop group was off task compared to 0.8% of the iPad group. The openness of the iPad screen and the inability to have multiple windows open may have contributed to this result. The surveys showed students felt the iPad was more conducive to showing work and justifying their actions to groups and the class. Survey responses showed 82% of the iPad group used the technology to show information to classmates versus only 47% of the laptop group. Also, 53% of iPad group took advantage of the device for reading materials but only 16% of the laptop group used it for this reason.

Fisher et al., (2013) found iPads could be used not only for calculations but also for collaboration among students. It enabled the participants to explain their reasoning behind how they solved a problem and to share and defend their work to their peers. The Common Core State Standards (CCSSI, 2010) for mathematical practice states students will “construct viable arguments and critique the reasoning of others” (p. 298). They found students benefited from sharing their knowledge by being the teacher for others. This helped to strengthen their understanding of the mathematical content. The iPads served “as a public center of communication in which multiple students can view, discuss, and interact with the device simultaneously” (Fisher et al., 2013, p.176).

As more emphasis is placed on creating constructivist-oriented learning environments that encourage rich discussions among participants, this study was beneficial because it is one of the first to focus on how iPads can be used to enhance collaboration and communication in the classroom beyond the abilities of a laptop. This new technology revealed the many benefits to incorporating it into a student-centered learning environment at the college level. More research will need to be completed to find if its benefits transfer to the K-12 level of education.

iPad Use in the Fifth Grade- Mathematics Classroom

Castelluccio (2010) found teachers are beginning to use the iPads to engage, introduce, practice, and reinforce learning concepts. Castelluccio stated, "The iPad has specialized applications in which multiple sense (e.g., auditory, visual, and tactile) are incorporated; the use of multiple sensory inputs has been shown to reinforce student learning and to achieve a variety of mathematics objectives" (as cited in Carr, 2012, p.270). To add to the scholarly research, Carr (2012) completed a study with fifth-graders researching if iPads affected mathematics achievement when used for game-based learning.

Carr's (2012) quasi-experimental study was conducted with two 5th grade classes in which the experimental group used the iPads as one-to-one computing devices daily during mathematics class for nine weeks. A pretest/posttest was used to analyze if the iPads had a positive effect on student achievement. Using ANOVA to analyze the data, the experimental group saw a 6.74% increase in pretest to posttest scores whereas the control group saw a 6.67% increase. This difference was not large enough to be deemed significant.

Carr's (2012) findings showed iPads did not have a significant influence on students' mathematics achievement. When listing limitations, she stated students in the study had limited access of the iPads, which may have played a role in the findings. Carr's research highlighted some of the issues of technology availability and the possible impact it has on instruction. Suggestions for future research were to conduct studies where the students have 24-hour access to the technology, increase in the intervention duration, using a larger sample size, and collecting qualitative data. Carr stated the verdict for one-to-one devices has been mixed thus far. As more implementation occurs, more studies are needed to determine the benefits of iPad use in the mathematics classroom.

iPod Touch Use in the Third Grade- Mathematics Classroom

With limited research on iPad use to examine, one study that can provide a glimpse into its usefulness is Kiger's et al., (2012) research with third grade mathematics achievement using the iPod Touch technology. Although the iPod Touch has limited capabilities compared to the iPad, it has similar technological features. This nine-week project used iPods to promote a mobile learning intervention (MLI) to practice multiplication skills through multiple available math apps. The following research questions were addressed.

1. Does participation in the MLI explain a significant amount of variation on a post-intervention multiplication test controlling for several covariates including prior student achievement? If so, what is the influence of the intervention relative to the control variables?
2. Does participation in the MLI explain a significant amount of variation on the most difficult post-intervention multiplication items controlling for several covariates, including prior student achievement? If so, what is the influence of the intervention relative to the control variables? (p. 64)

Kiger's et al. (2012) study was conducted in four classrooms in which two practiced math facts by using flash cards each day and the other two practiced using math apps downloaded onto iPod Touches. The findings showed the MLI students outperformed the other students on the multiplication posttest with the effect size being a significant 0.22 indicating a small effect. "MLI participation was the most influential 'explainer' of test performance excepting the pretest" (p. 75).

The Kiger et al. (2012) study in contrast to Carr (2012) showed a positive effect on student's mathematic achievement. With multiple studies finding conflicting results, this reinforces the need for more research of its use in the classroom.

iPad Use in the High School- Science Classroom

Physics courses enable students to apply the mathematics they have learned in meaningful ways. Students use analytical skills to solve word problems that can represent real world situations and begin to understand the background of many of the technological advances we use today. Success in physics can help open the doors to many STEM careers for our students. The question in the next study was whether iPads could facilitate that success. Through a project called iPad Enhanced Active Learning (iPEAL), Van Dusen & Otero (2012) set out to determine the effects iPads would have on students' interactions with and relationships to physics. The study was conducted with five high school physics classes consisting of approximately 140 junior and senior level students. The project provided a classroom set of iPads and activities designed to supplement the traditional physics assignments. For example, the students used the iPads to create screencasts of how to solve problems from the textbook.

Van Dusen and Otero (2012) based their research on the idea that if a learner is actively engaged in something personally meaningful, then learning is more likely to occur. The study was focused on providing a positive experience in physics class by incorporating the iPads into instruction. Through the use of field notes, artifacts, video recordings, student surveys, and student interviews, the researchers found the iPads had an effect on four specific areas. First, by using iPads for data collection, analysis, and collaboration, the students were able to construct their own learning based on evidence they collected rather than knowledge from the teacher or book. Secondly, the iPads created excitement for learning and students began to come to work on physics projects outside of class time. Thirdly, the iPads increased student agency as students used the screencasts to take more responsibility for their own learning. Finally, students experienced an impact on their social status of being a member of this learning community as others verbalized a desire to be part of their learning community.

Van Dusen and Otero (2012) concluded the iPads created an environment that promoted a positive relationship between students and physics. This could set up a situation where the students would continue to enroll in future physics courses.

iPad Use in a One-to-one Environment

As schools move to more technology-infused environments, one of the biggest technological changes in education today is the implementation of one-to-one programs. These programs can be loosely explained as every student having their own device such as a laptop, iPad, or another tablet device to be used at home and school; however, the school largely defines the organization of that implementation. Penuel (2006) stated the policies vary among institutions. Some may have all students buy the same device, while others may have devices student rent or lease for the school year. Others may have students check them in and out each school day but not take them out of the school building. Another option is to follow a bring your own device (BYOD) policy where students may choose the best option for them. However, in each case, there are three common characteristics: students each have a device, Internet is provided through wireless access, and the devices are used for academic tasks such as completing homework and assessments and for presentations. Overall, "ubiquitous, 24/7 access to computers makes it possible for students to access a wider array of resources to support their learning, to communicate with peers and their teachers, to become fluent in their use of the technological tools of the 21st century workplace" (p.332).

One-to-one Tablet Initiative Private Middle School Program

Oliver and Corn (2008) completed a study to measure differences in students' technology use and skills after a one-to-one tablet initiative with middle-school students. In this research project, participants were students in the sixth through eighth grade at a private middle school in the US who completed a survey before and after participating in a one-to-one program for a year. The survey asked questions about how satisfied they were with technology use at their school, their technology experiences in the classroom, how it was used in the different content areas, and their technology skills. A control group also completed the surveys, as well. The researchers completed observations of the classrooms to collect data on how the technology was being implemented.

Oliver and Corn (2008) found students in the one-to-one group were more satisfied with the technology use at their school, more time was spent in class using technology, and significantly more frequent use of technology in the mathematics and science classes. Observations showed more project-based learning, teachers acting as coaches, and student-centered projects assigned. However, teacher-centered instruction was still the most common approach to teaching in the classroom. Even with one-to-one technology, teachers were still not using them to create learner-centered environments that would encourage collaborative learning.

One-to-one iPad Initiative PreK-4th Grade Program

One-to-one technology integration is appearing not only at the secondary and university level, but also in our elementary schools. Milman, Carlson-Bancroft, & Boogart (2012) analyzed the implementation of a one-to-one iPad program at a PreK-4th grade school. They researched how teachers and students were using the iPads for teaching and learning, specifically how they were being used for differentiation and how they were used across content areas.

Milman's et.al. (2012) mixed methods study collected data by completing 68 observations for a total of 50 hours, and by collecting surveys. Although the study is in the preliminary stages, they have found the use of iPads have netted the following results. Student engagement has been very high and helped with attention issues of the students. Even after months of use, students were still excited to participate in lessons that incorporated the iPads. Also, the observations showed teachers taking a facilitative approach to teaching when the iPads were in use. Students showed a collaborative spirit as they assisted each other with activities. Finally, all teachers were able to use the iPads to differentiate instruction in their classrooms. Overall, the iPads were being successfully incorporated into instruction to provide for an engaging, personalized learning experience.

One-to-one iPad Initiative Private Middle/High School Program

Heinrich (2012) at the Longfield Academy in Kent, England conducted research of the students at the school who were participants in a one-to-one iPad initiative. The school has approximately 960 students in year 7 to year 13 and 76% of the students have iPads. The school's goal of the one-to-one program was to provide students with engaging lessons, the ability to use technology in every lesson, and for the technology to improve learning. The academy's research done prior to the one-to-one implementation showed iPads were a significant tool to support learning (Learning Exchange, 2011), students preferred it to a laptop and it aided learning (Gliksman, 2011), the device was beneficial for note taking (Vrtis, 2010), and encouraged group collaboration (Garcia & Friedman, 2011). Heinrich pointed out most of the research available was based on class sets of the devices rather than a one-to-one setting. Their study strived to determine the implications of all students having their own device. Surveys were collected from students, teachers, and parents to determine the success of the program.

Heinrich (2012) first found the implementation of the iPads into instruction to be abundant. 84% of students reported iPad use in one to ten lessons per week with 27% of those stating use in 6 to 10 lessons per week, and 12% reporting iPad use in the majority of lessons. Teachers corroborated those numbers by 80% reporting use in 1 to 10 lessons, 38% in 6 to 10 lessons, and 17% using the technology in the majority of their lessons. It was found the majority of the lessons were in English, math, and science and determined offering these devices in a one-to-one environment played a significant role in how much the devices were being used.

Heinrich (2012) identified three main implementations of the iPad: researching topics online, using mind-mapping tools, and creating presentations. The devices were also used for traditional activities such as word processing and watching videos. Collaboration was also an aspect used frequently with 42% of students and 52% of teachers reporting the use of collaboration. When students were asked what were the benefits of using an iPad compared to the pre-iPad classroom, some of the responses were easy internet access, making movies, educational games, mind mapping, apps for learning, communication with teachers, creating and delivering presentations, and annotation of texts. Heinrich reported, "There is a clear message that students regard the iPad as a tool that enables them to work more efficiently and thus, by extrapolation, more productively" (p.23). When teachers were asked how the iPads had changed their setting, they stated the personal benefits were the ability to create podcasts, easier lesson planning and sharing of resources. The classroom benefits were creating engaging lessons for students, immediate research capabilities, ease of differentiating instruction and immediate feedback for students of learning.

Overall, Heinrich (2012) found 90% of students reported being happy with the use of iPads for learning and 77% of teachers were happy to regularly use them. Both participant groups felt they could work more effectively with the iPads and their level of collaboration had improved. In the end, it was reported the devices had a significant and very positive impact on learning and teaching, and there was an expectation the impact would be noticeable in future achievement.

One-to-one Laptop Initiative Middle School Setting

With the lack of studies completed addressing the effect of one-to-one iPads on academic achievement in the middle school mathematics and science classroom, Dunleavy's and Heinecke's (2007) study can be used to shed some light on the benefits of a one-to-one program. They conducted research in a middle school that used Apple iBooks laptops as their mobile devices. The urban school in the study had 972 students in grades six through eight, a percentage poverty of 59.67 and a percentage minority of 87.20. As the students entered sixth grade, approximately one third of the students were randomly assigned to the one-to-one program. The students were allowed to use the devices in every class and take them home during the week. However, devices were required to be left at school on the weekends.

Dunleavy and Heinecke (2007), by using a pretest-posttest control-group design, analyzed the effects of the laptop implementation on eighth graders who had used the technology for two years. The students' fifth grade pre-existing mathematics and science achievement scores on the state standardized test were used as the covariate to equate the treatment and control groups. Using ANCOVA, the researchers used the scores on the eighth-grade standardized test to determine any effects as a result of the intervention of the one-to-one program. The participants in their study consisted of 54 students in the treatment group and 113 students in the control group.

Dunleavy and Heineche (2007) had three main findings from the analysis. First, after accounting for differences using the pretest scores, the laptop initiative was found to have a small, significant, positive effect (0.24) on the science posttest scores. Secondly, this effect was found to be more significant for males (0.55) than females (0.04). Finally, in regards to mathematics, the laptop treatment had no significant impact on achievement.

In discussion, Dunleavy and Heineche (2007) brought up some interesting questions to be addressed in future studies. With a significant effect on students' science achievement found, why does that not carry over to mathematics? Was the technology implemented differently in science class or were there possibly more technological resources available for science content? Why was the positive effect in science found to me larger in males than females? Although this study helped to shed light on whether one-to-one programs have a place in education, it also leaves a need for more research in this area.

Summary

Throughout the last decades, technology has flourished in our schools and more emphasis has been placed on creating student-centered environments that follow the tenets of Constructivism. A constructivist style of teaching has been shown to be effective with academic achievement significantly higher for those students learning in a constructivist setting. Ayaz's and Sekerci's (2015) meta-analysis showed strong effect sizes for using a constructivist approach in the classroom, with the strongest effects found at the high school and college level.

Through the use of meta-analyses, Bayraktar (2002) found CAI was significantly more effective than traditional instruction when analyzing 42 studies of high school and college level science classes. Li and Ma (2010) discovered the same results in the area of mathematics and not only did CT have a positive effect on mathematics achievement but it also had larger effects when paired with a constructivist-learning environment.

With the previous studies showing positive effects of a constructivist learning environment and the use of computer technology on mathematics and science academic achievement, more research is now needed to see if that effect translates to the use of iPads in a one-to-one setting. Research has shown the use of iPods positively effected mathematics achievement when used in the classroom (Kiger et al., 2012); however, there have not been large amounts of studies completed on the iPads effects, especially in a one-to-one setting. The research of one-to-one iPads have focused mostly on analyzing students' and teachers' perceptions of the technology and how the iPads are being implemented with little research conducted on actual achievement scores (Oliver and Corn, 2008; Milman et al., 2012; Heinrich, 2014). Research on one-to-one settings with laptops has shown this type of implementation is effective in raising science achievement (Dunleavy and Heineche, 2007).

A key component to a one-to-one initiative, though, is our teachers' abilities to create effective technology-infused classrooms. Koh et al. (2014) showed not all teachers have the strong C-TPACK necessary to successfully implement technology into a constructivist-learning environment, especially those who have been teaching for a long period of time and those teaching at the elementary level. With more and more iPads and tablets appearing in school districts, it is not only imperative that more research be conducted to determine the effectiveness of these technological tools on the academic achievement of our students but that continued professional development be provided for teachers to ensure they have the knowledge needed to incorporate the tools effectively into their mathematics and science classrooms.

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IMPROVING EFFICIENCY OF OPERATIONAL EDUCATION BY USING VIRTUAL REALITY

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ABSTRACT: Virtual reality is one of the novel technologies used mostly for entertainment purpose. It is really a good environment to enhance the feeling of user during playing the game and to obtain a realistic environment. Besides, this technology can be utilized as an educational tool. By this way, the students will learn the subject by using more senses in a funny method. The meaning of operational education is a kind of hands on education in which a series of procedures should be completed in a correct order and a limited time. However, the tools and hardware are needed for hands on education which means high cost. Virtual reality is one of the solutions to achieve operational education without using many hardware and tools by it is capability to simulate the realistic environment. Actually, it has been already started to use in education of military and medical students. In our case, we focus on the education of marine engineers which includes many operations of a very complex power system. Therefore, it will be possible to teach many kinds of mechanical operations with only virtual reality tools and eliminating a large amount of expensive hardware.

Keywords: virtual reality, marine engineer, operational education, innovation, technology

INTRODUCTION

The virtual reality (VR) is providing an environment to the user in which the activation of more senses is possible. The VR studies are actually not very new. In the literature, the study “Sensorama Simulator” was carried out in 1962 by Mortan Heilig. In this study, a machine was designed aiming to make feel a theatrical drama with all senses of a human which is shown in Fig.1. The machine consists of wide angle stereoscopic view, a vibration mechanism, stereo audio system, and aromatic odor release system.

Figure 1. The “Sensorama” Simulator

In1963, Ivan Sutherland studied SKETCHPAD in his doctoral theses which integrated stereo head mounted display (HMD), position tracking, and graphics engine. Then, Sutherland made another study in 1968 which is closer to the modern technology. In this study, he designed a head mounted 3D display which is called “The Sword of Damocles” because it was very heavy and hanged on the ceiling. The term “virtual reality” was firstly used by Jaron Lanier in an interview in 1989. In the following years, there was an improvement in entertainment and game sector. Therefore, the VR studies are also improved. For example, Nintendo Company produced “Virtual Boy” in 1995 which is the first mobile game console with 3D display supplying device.

In the last decade, VR has started to be more popular especially in the entertainment sector due to its user friendliness, flexible interface, simplicity in design, and realistic features. Especially VR glasses have serious advancement in 3D games in which the player sense the environment much more realistically with immersed features. Using immersed environment play a serious role for influencing the senses. Essentially the visual sense is used which has a great influence on other senses. It can be understood by playing a 3D game that despite you are stable you feel as you are really moving only with visual effects. This can be seen in Figure 2.

Figure 2. The Effect of Visual Sense

It is very well-known that activation of more senses makes the education much better and long lasting. In this respect, VR is getting more interesting for education purpose, as well. The education can be more interesting, funny, interactive, realistic, and clear by using VR environment. The learning period can be shorter by this way. Besides, the new generation is immersed in technology. They met with cell phones and tablets when they were only a baby. As a result, they are almost addicted to games. The fondness of them to game technologies can be seen in Figure 3. These are images from a game fair in Istanbul (GAMIST 2017 Exhibition).

Figure 3. Interest of Young Generation to Game Technologies in GAMIST 2017 Exhibition

Therefore, we have to make the education environment suitable for them. The game like lessons will be more effective for them. In brief, developing the educational materials with VR and its adaptation to the educational life is very flexible, easy and effective way. Actually, it has started to be used in some sectors such as military, medicine, etc. but it is still not sufficiently popular.

In this study, the effect of VR on operational education is focused on and its usage for education of marine engineers is discussed. The courses which are related to operation of machines are shown in the syllabus of marine engineering education and the necessity of improving the education environment with VR is stated. By this way, a wide variety of ship and machinery environments can be developed with very few hardware which is a great opportunity for the students to meet very different ship types.

OPERATIONAL EDUCATION

Most of the occupations need some applications besides the theoretical background. That is why the education programs consist of theoretical courses and application courses such as laboratories. However, the laboratory studies are not sufficient to express all kinds of applications. For example, the training of operations in a terrain or a medical operation cannot be categorized as a laboratory study. At this point, we categorize some of the application trainings as operation. The meaning of operation here is mainly covering the applications which consists of some sequential steps and carried out in a special area or terrain. For example, the training of a soldier in a terrain can be categorized as operational education.

VR has been used for such kind of training purposes mainly in medical training and military training sectors. In Figure 4 some of the sample trainings for medical and military sectors are shown.

Figure 4. Sample Trainings for Medical and Military Sectors

Operational Education of Marine Engineers

Marine engineering is one of the operation dense occupations. In this context, the meaning of operation is taking the necessary tasks and steps in a sequence to run a system and maintaining it running without problems. The main job of the marine engineer is to run and maintain an existing marine power system. There is an educational standard of marine engineering which is determined by International Maritime Organization (IMO). This standard is called Standards of Training, Certification and Watchkeeping (STCW) and it is mandatory to keep the mariners occupational knowledge at a certain level who work around international waters. In this standard, the minimum level of the necessary course content is determined and every maritime training institution should meet these standards to be able to get international certificate. In these standards there is an operational level and management level categorization. When we have a close look at the STCW, we come across many definitions and necessities about the operations on marine systems. Besides one of the obligatory item is having an engine room simulator (ERS) which is for training of students to have overview knowledge about the systems on board the ship and to be able to operate them truly. Even more the necessary actions to be taken in case of troubles are considered. To be able to reflect the meaning and importance of “operation” in maritime education we listed the courses related to operation of marine systems in ITU Marine Engineering Department in Table 1. As it can be seen in the table, there are numerous courses directly related to operation of different marine systems.

Table 1. The Courses Related to Operation of Marine Systems

#	Course name
1	Operation and Maintenance of Marine Engines
2	Marine Boilers and Operation
3	Operation of Steam and Gas Turbines
4	Marine Diesel Engines I
5	Marine Diesel Engines II
6	Engine Room Simulator (ERS) I
7	Engine Room Simulator (ERS) II
8	Terminal and Tanker Operations
9	Marine Auxiliary Machinery I
10	Marine Auxiliary Machinery II

One of the important courses is engine room simulator in which the student can see the whole systems in a schematic form. There are two modules of ERS: one of them is PC Workstation and the other is mimic panel which can be seen in Figure 5. In workstation and especially mimic panel, the student can see the whole system but it is only a schematic drawing. In mimic panel the student can see the whole systems at once and operate the system through the buttons on the panel. The situation of the equipment can be seen through the lamps (For example green light for running or open). For example, to open a valve or to run a pump they push the related button. However, the student doesn’t know about the real shape of that system or equipment. For instance, while preparing the main engine to operation, the indicator valves should be closed. In mimic panel, the student can see these valves but in a real ship they will most probably not be able to recognize and find these valves. Besides, in real ship they will not be able to see the whole system and their situation through the pilot lamps. Even more, the present simulators which are based on hardware have limitations of ship type. This kind of simulators can be only one type of a ship. You should prefer a ship type such as crude oil tanker, container ship etc. and you are dependent on that type.

(a)

(b)

Figure 5. Engine room simulator (a) Mimic panel, (b) Work Station

In case of virtual environment, you can generate any kind of ship type and any kind of machinery type freely. There will not be a hardware dependency. Besides, the maintenance options will be much better and cheaper. In a hardware dense simulator, the parts will be broken and will have some troubles by time resulting in very high expenses which will be eliminated by virtual reality environment. Some kinds of 3D virtual environments can be seen in Figure 6. As it can be seen, the whole environment is virtual and there is no hardware such as relays, lamps, buttons etc. You can freely simulate any kind of environment and walkthrough and take actions through that environment. Therefore, the students will be able to see many different kinds of machinery. It will be possible to simulate latest types of machinery and the students will learn the newest technology.

Figure 6. Virtual machinery environment and 3D Simulated Engine Room (Courtesy of BAE Systems and Unitest Marine Simulators)

CONCLUSION

Improvement of technology gives us many usable tools which makes our life more easy and efficient. The new generation grows up with computers, tablets, and games. They spend a serious time with playing computer games. These days we have an opportunity to educate them in a way they will like. Therefore, we should find some methods to make education more game like which will be more interesting for contemporary students. We have necessary tools to do that. Besides, it will be very effective to show the students as various types of equipment as possible especially in engineering sector. As we mentioned above we can also introduce some feeling and sensing to learning process which will be much more effective and long lasting. We can and should achieve this by utilizing virtual reality environments.

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ROLE OF INFORMATION TECHNOLOGY IN EDUCATION IN INDIA

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ABSTRACT: The focus of this paper is to examine the role of Information and Communication Technology (ICT) in higher education in India. The emergence of ICT has fundamentally changed the practices of not only business and governance but education as well. While the world is moving rapidly towards digital media, the role of ICT in education has become increasingly important. There has been an unprecedented growth in the use of ICTs in teaching, research and extension activities. The sudden boom in Information Technology has transformed the way how knowledge is disseminated today. One of the changes it has brought about is the way how teachers interact and communicate with the students and vice-versa. Given the fact that higher education in India is plagued by the challenges of inadequate technology access and inequity coupled with economic considerations and technological know-how, it remains to be seen how Information and Communication Technology can actually burgeon the students and how it can foster change in this aspect. Moreover, this paper explores the emancipatory and transformative potentials of ICT in higher education in India. Finally, this paper assesses how Information Technology has facilitated the growth in interactive learning and what has been its impact in the higher educational scenario in the country.

Keywords: education, information, technilogy, teaching, collection,

INTRODUCTION

The emergence of Information and Communication Technology (ICT) has fundamentally changed the practices of not only business, governance or education but every spheres of human endeavour. As the world population edged to 7 billion in 2011, it has profound implications in every sphere (UN, 2013). India has a massive 1.2 billion population (Census, 2011) of which a high proportion of them are young. The demand for education in developing countries like India has skyrocketed as education is still regarded as an important bridge of social, economic and political mobility. India has innumerable challenges in terms of infrastructure, socio-economic, linguistic and physical barriers for people who wish to access education[1]. However, it is hoped that ICT can transform the educational scenario in the country. But then, can it address these needs and perform multiple roles in higher education to benefit all stakeholders? The emancipatory and transformative potentials of ICT in higher education in India has helped increase the country's requirement of higher education through part-time and distance-learning schemes. It can be used as a tool to overcome the issues of cost, less number of teachers, and poor quality of education as well as to overcome time and distance barriers (McGorry, 2002).[2] Mooij (2007) states that differentiated ICT based education can be expected to provide greater reliability, validity, and efficiency of data collection and greater ease of analysis, evaluation, and interpretation at any educational level. While the world is moving rapidly towards digital media, the role of ICT in education has become increasingly important. It has transformed the way how knowledge is disseminated today in terms of how teachers interact and communicate with the students and vice-versa.[3]

Need of the IT

1. Education is a life long process therefore anytime anywhere access to it is the need
2. Information explosion is an ever increasing phenomena therefore there is need to get access to this information
3. Education should meet the needs of variety of learners and therefore IT is important in meeting this need
4. It is a requirement of the society that the individuals should posses technological literacy
5. We need to increase access and bring down the cost of education to meet the challenges of illiteracy and poverty-IT is the answer

The information society challenges the education system. In recent years, the speedy, effective and global communication of knowledge has created a new foundation for co-operation and teamwork, both nationally and internationally. The increasing role played by information technology in the development of society calls for an active reaction to the challenges of the information society. Already, new and greater demands are being made as to the core qualifications of individuals, as well as to their understanding and knowledge of the consequences of the introduction of information technology for the work and organisation of a company. Companies are no longer forced to gather all their functions in one place. The knowledge-intensive functions such as development and marketing can be sited in countries where the labour market can supply highly educated employees, whilst production itself can be moved to low wage countries. The result is the efficient handling, processing, co-ordination and administration of company resources, which is decisive for the competitiveness of the company. In a society which is becoming increasingly dependent on information and the processing of knowledge, great demands are therefore made that the individual should have a solid and broad educational foundation on which to build. Educational policy in the information society must ensure that.[4]

Table 1. Changes in Students and Teachers Roles in Learner-Centered Environments.

Changes in Teacher Role	
A Shift from	**A Shift to**
Knowledge transmitter, primary source of information, content expert and source of all answers	Learning facilitator, collaborator, coach, mentor, knowledge navigator and colearner
Teacher controls and directs all aspects of learning	Teacher gives students more options and responsibilities for their own learning
Changes in Student Role	
A Shift from	**A Shift to**
Passive recipient of information	Active participant in the learning process
Reproducing knowledge	Producing and sharing knowledge, participating at times as expert
Learning as a solitary activity	Learning collaboratively with others

Sources:(Table adapted from one developed by Newby et al.,2002)

Higher Education Scenario in India

India has one of the largest higher education systems in the world consisting of over 651 universities according to UGC as on 2013. Besides there are 31,324 colleges of higher learning in the country as on August 2011 according to the Higher Education in the 12th Five-Year Plan Report (2012-17). The number of students enrolled in the universities and colleges has increased since independence to 13,642 million in the beginning of the academic year 2009-10 with 1,669 million (12.24%) in the university departments and 11.973 million (87.76%) in the affiliated colleges (MHRD, Annual Report, 2009-10). However, this growth in numbers does not reflect much improvement in the delivery of higher education in the country.[5]

Table 2. Type-wise classification of Universities in India.

Sl. No	**Type of Institution**	**No. of Institution** (as on 2006)	**No. of Institution (As on 2013)**
01	Central Universities	20	44
02	State Universities	217	310
03	Private Universities	8	168
04	Institutions Deemed to be Universities	104	129
Total		349	651

(Source: UGC excluding institutions of national importance)

The higher education system in India continues to suffer due to inadequate access to technology and inequity. However, the application of ICT in higher education has not only brought about diversification in higher education but has also fostered new avenues for international mobility of traditional and non-traditional students. While it is believed that ICT can transform the educational scenario in the country, it should address the needs and perform multiple roles in higher education to benefit all stakeholders. This sense of urgency and the continuous implementation of ICT in higher education have led many universities and colleges into a more action-oriented adaptation approach. It is observes that the focus is often more on the end product than on the premises and processes behind a well-functioning incorporation of ICT in teaching and learning.[6]

ICT application for quality improvement in formal and Non-formal education:

ICT applications are becoming indispensable parts of contemporary culture, spreading across the globe through traditional and vocational education. In Indian scenario, mainly education system has three tiers primary (including nursery and preprimary), High school or secondary level (High and senior secondary levels) and the college or higher level (including college, university levels). In all these levels of education ICT can be utilized for better teaching learning process and improving quality of education. Using multimedia in education results in the increasing productivity and retention rates, because people remember 20% of what they see, 40% of what they see and hear, but about 75% of what they see and hear and do simultaneously. Interactive whiteboard helps teachers to structure their lessons, supports collaborative learning, can help to develop student 's cognitive skills, enables ICT use to be more integrated into classroom. Government of India has announced 2010-2020 as decade of innovation. Reasoning and critical thinking skills are necessary for innovation. Foundation of these skills can be laid only at primary level of education. Students who enter school are very curious, creative, and capable of learning many things. At this level, statement Picture is worth than thousand of words is very much true in case of teaching –learning process. Befriending ICT in the initial stages of education will help young people come to terms with what lies ahead. Students at this level take much interest in cartoons. They understand more through animated pictures. Hence if the same environment is created in schools by using ICT for teaching kids at primary level may bring drastic changes in the education scenario. Nursery students can be taught by showing pictures, animals, fruits etc. With the help of ICT tools students at this level are able to grasp a lot by hearing voices or sounds and animated motion of various animals. Language learning is also taught at this level. To know a new language at this age is easier as compared to other levels. Multimedia projector & computer can be used to teach phonetics and pronunciation. Lessons, poems & lectures by eminent scholars stored in computers or other ICT tools can easily be shown to the students time and again anywhere. Such type of teaching and learning retains for long time in the minds of the children. At high school level subjects like History, Geography, Political science, Physics, Chemistry, Biology, Physical education etc are taught. Lessons in these subjects can easily be taught by showing small movie related with the subject to create interest among the students. Such type of movies and related multimedia material is easily available at academic repositories and from various related sites with the help of Internet. Internet is basic tool which can be utilized by teachers and students to find any information on any topic. This type teaching – learning makes the environment very interactive and is liked by students. Educational and practical CD's available in the market make this task easier to implement.[7] At college level various facilities like computers, Electronic Board, Edusat facility initiated by various state Governments, MM projector and other peripheral devices related with teaching learning process are easily available. Various programs running on Edusat are also very helpful for the students. Soft skill program can help students in getting their placements in reputed Multi National Companies (MNCs). State level quiz and seminar can also be conducted with the help of Edusat infrastructure and can be transmitted throughout all institutes. Edusat can be used for providing training to teachers on the latest subjects and technologies and can save lot of time and money of governments. In Haryana Edusat project is being implemented at school and college level and is being used for transmitting lectures according to syllabi. In Non-formal learning, learners can access information and learning materials from anywhere and at any time. It includes distance education and other open learning systems. There are various functions to be performed with the enrolment of students in any course of distance education in any University or institute. Functions include allotment of unique number (called reference number/roll number), providing books, providing information related with installment of fees and details thereof to name a few. Out of all these activities some of these may be performed well with the help of ICT Tools. In the distance education ICT can be used for better management of records by making a complete database of all the students in various courses. Once the students are enrolled, a unique number is generated called reference number and it is provided to the particular students. Short Message Service (SMS) of Mobile phone may be utilized for this purpose. Mobile phone is one major ICT tool and can be used for the purpose. Other information related the PCP, Exam dates can easily be sent to the students through SMS by Universities/ Institutes concerned. Moreover the enrolled students can be given username and password for using various online services and resources in the form of academic repositories maintained by institutes.[8] All such instructional material may be uploaded at the University portal and CDs of those lectures may be provided to the students instead of printed or hard copy material. Online fees payment system can also be made on the portal of concerned University or Institute. Students will be saved from a lot of hardships they face in depositing fees, attending PCPs, taking exams and many more. Exam results in such cases may be provided online on the same day as same is happening in case of online exams and entrance tests. This would help to sort out the problem of the delay in declaration of results of various exams by various universities. But all this must be the case for the Non-formal education system. Advantages of utilizing such tools include saving of lot of paper work and help the environment making it pollution free. This will also bring transparency in the whole system of functioning. Role of IT in education

Access to variety of learning resources

In the era of technology. IT aids plenty of resources to enhance the teaching skills and learning ability. With the help of IT now it is easy to provide audio visual education. The learning resources are being widens and widen. Now with this vivid and vast technique as part of the IT curriculum, learners are encouraged to regard computers as tools to be used in all aspects of their studies. In particular, they need to make use of the new multimedia technologies to communicate ideas, describe projects, and order information in their work.

Immediacy to information

IT has provided immediacy to education. Now in the year of computers and web networks the pace of imparting knowledge is very very fast and one can be educated anywhere at any time. New IT has often been introduced into well-established patterns of working and living without radically altering them. For example, the traditional office, with secretaries working at keyboards and notes being written on paper and manually exchanged, has remained remarkably stable, even if personal computers have replaced typewriters.[9]

Any time learning

Now in the year of computers and web networks the pace of imparting knowledge is very very fast and one can be educated. One can study whenever he wills irrespective of whether it is day or night and irrespective of being in India or in US because of the boom in IT.

Collaborative learning

Now IT has made it easy to study as well as teach in groups or in clusters. With online we can be unite together to do the desired task. Efficient postal systems, the telephone (fixed and mobile), and various recording and playback systems based on computer technology all have a part to play in educational broadcasting in the new millennium. The Internet and its Web sites are now familiar to many children in developed countries and among educational elites elsewhere, but it remains of little significance to very many more, who lack the most basic means for subsistence.[10]

Multimedia approach to education

Audio-Visual Education, planning, preparation, and use of devices and materials that involve sight, sound, or both, for educational purposes. Among the devices used are still and motion pictures, filmstrips, television, transparencies, audiotapes, records, teaching machines, computers, and videodiscs. The growth of audio-visual education has reflected developments in both technology and learning theory.

Studies in the psychology of learning suggest that the use of audio-visuals in education has several advantages. All learning is based on perception, the process by which the senses gain information from the environment. The higher processes of memory and concept formation cannot occur without prior perception. People can attend to only a limited amount of information at a time; their selection and perception of information is influenced by past experiences. Researchers have found that, other conditions being equal, more information is taken in if it is received simultaneously in two modalities (vision and hearing, for example) rather than in a single modality. Furthermore, learning is enhanced when material is organized and that organization is evident to the student. [11]

Authentic and up to date information

The information and data which are available on the net is purely correct and up to date. Internet, a collection of computer networks that operate to common standards and enable the computers and the programs they run to communicate directly provides true and correct information.

Online library

Internets support thousands of different kinds of operational and experimental services one of which is online library. We can get plenty of data on this online library.

As part of the IT curriculum, learners are encouraged to regard computers as tools to be used in all aspects of their studies. In particular, they need to make use of the new multimedia technologies to communicate ideas, describe projects, and order information in their work. This requires them to select the medium best suited to conveying their message, to structure information in a hierarchical manner, and to link together information to produce a multidimensional document. [12]

CONCLUSION

Quality in education through ICT and its awareness among stakeholders will have positive impact on the society. ICT can be helpful in quality and standards of education by implementing it in various phases of education. ICT can be employed in formal and Non-formal types of education and would eventually make the learners employable and socially useful part of the society. By employing ICT in teacher training can save a lot of money of the Government. Moreover a lot of qualitative improvement can be seen as resource persons for the training can be best of the world. By employing ICT in administration can help in solving the problem of Absenteeism of students and teachers. Good quality content is one of the major issue and directly affects the standards of education and quality. By overcoming the certain challenges involved in the process of education can help a lot in this side. Conclusively a lot of quality improvement is possible after careful and planned implementation of ICT in education by various stakeholders.

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SUPPORT AND CONSIDERATIONS FOR IMPLEMENTING THE SURVEY TOOLKIT PROJECT-BASED CURRICULUM USING TINKERPLOTS®

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ABSTRACT: The Survey Toolkit (Walsh, 2009) curriculum, including use of TinkerPlots® technology tools, was developed based on a review of the research providing guidance in best practices and methodology in teaching survey research to elementary and middle school students. The paper presents the literature review beginning with the development and support of statistics education and it importance for informing and decision-making, especially relevant today due to social media influences in persuading public opinion and trafficking of fake news. The review discusses implementation concerns and pedagogy issues in delivery of a statistics curriculum. Discussion of research directions with consideration of The Survey Toolkit curriculum using TinkerPlots® as a potential curriculum for authentic student data generated project learning is presented.

Keywords: TheSurveyToolkit curriculum, integrating TinkerPlots®, elementary/middle schoolstatistics, authenic/stochastic/learning; staff development pedagogy

INTRODUCTION

The Survey Toolkit Collecting Information, Analyzing Data and Writing Reports (Walsh, 2009) curriculum was written to provide a methodology for upper elementary and middle school students to develop a survey research projects. The curriculum is integrated with the *TinkerPlots*® software program allowing for visual data analysis using graphing to develop statitical conceptual thinking (e.g., ideas about variablility and measures of center), describe data plots, and make inferences beyond the data. The curriculum includes *The Survey Toolkit Resource Manual* (Walsh, 2010) written to support *The Survey Toolkit* text providing additional support in developing survey questionnaires, presenting a notetaking strategy for writing a research report, selecting a sample, and providing teaching resource appendix activities.

During development of *The Survey Toolkit* curriculum a review of the literature was conducted to provide guidance and information about best practices to support teachers in implementating a statistics research project for students to learn effectively. More recently research on teaching survey and data analysis was studied to review current information and trends in this curriculum area supporting authentic student project work in learning statistics, particularily focusing on the use and integration of technology programs like *TinkerPlots*®.

The specific topics of the review will be examined in the paper and include historical development and support for teaching statistics, national guidelines and projects for developing a statistics curriculum, appropriate student statistics curriculum content and learning skills, student conceptions in developing statistical literacy, use of technology tools like *TinkerPlots*®, and teacher implementation considerations of a data analysis curriculum. A final discussion about the implications of the review of the literature related to use of *The Survey Toolkit* curriculum and need for further research is also presented.

Historical Development in Statistics Education

The study of statistics and probability is historically rooted, and more recently in the 20th century statistics began to emerge out of other disciplines. Shaughnessy (1992) reports that statistics and probability appears to have been an integral part of the mathematics curriculum in many European countries for some time dating back to the 17th century. Hacking (2006) review of past events reports the decade around 1660 was the birth time of probability. According to Hacking, in 1657 Huygens wrote the first probability textbook that was first to mention numerical measurements and included aleatory problems.

In *the Taming of Chance* Hacking (1990) argues that during the nineteenth century the erosion of the idea of determinism (i.e., the past does not determine what will happen next) was being replaced by the laws of nature or the enumeration of people and their habits. According to Hacking, society became statistical and most of the law-like regularities were first perceived in connection with deviancy (e.g. crime, disease, and madness) with government information based on statistical inference to improve and control a deviant subpopulation by classification. Hacking elaborates on society early use of statistics during this period, based on collection of data about people, including first attempts to use medical statistics as evidence for the efficacy of rates of cure and use of crime statistics for designing the most efficient jury system.

Garfield and Ben-Zvi (2007) discuss the development of the field of statistics education during the 20th century leading to more recent support from National Council of Teacher of Mathematics (NCTM) and other organizations. Figure 1 shows a summary of these authors research highlighting development and evolution of this separate discipline to provide understanding and insight for teaching today. More recent pedagogy and content focused on technology use for introductory statistics instruction using graphing calculators, with graphic simulations using multimedia (Moore, 1997). Garfield and Ben-Zvi, also highlight *Technology Innovations in Statistics Education* report on studies using technology to improve statistics learning at all levels from kindergarten to graduate school and professional development.

English and Watson (2015) report that since the introduction of statistics into the school mathematics curriculum (e.g., Australian Education Council 1991) there has been a growing awareness of the inadeuacy of focusing solely on the teaching of procedural skills in calculating statistics without adequate attention given to teaching informal inference, especially at the elementary level. Informal inference is the process of using the evidence provided by data to answer questions and write conclusions about variability beyond the data. Examination of the literature more recently provides support in teaching informal inference at the upper elementary and middle school level (Watson & Moritz, 1999; Ben-Zvi, 2006; Watson, 2008; Paparistodemou & Meletiou-Mavrotheris, 2008; Watson & Donne, 2009; Makar, 2013; Makar, 2015; Ben-Zvi, Bakker & Makar, 2015) along with activities used successfully with students to develop awareness of variation, at the heart of statistical reasoning. The use of technology programs, like *TinkerPlots*®, used in conjunction with curriculum supporting the learning of informal inference would need to be added to update the timeline shown below.

Figure 1. The Historical Development of the Field of Statistics Education

1944 – American Statistical Association (ASA) develops the section on training of statisticians that later became the Section on Statistical Education in 1973.
1948 – The International Statistical Institute (ISI) forms an education committee focusing on training statisticians, and later broadened to include training or education at all levels.
1967 – A joint committee is formed between ASA and NCTM on curriculum in statistics and probability for grades K-12.
1970's (early) – Instructional materials begin development to present statistical ideas.
1970's (late) – ISI creates a task force on expanding the teaching of statistics in the K-12 curriculum reporting the lack of coordinated efforts, appropriate instructional materials, and adequate teacher training.
1980's – Conferences on teaching statistics emerge including the first International Conference on Teaching Statistics (ICOTS) held in 1986 and has continued every four years.
1990's (early) – George Cobb and a working group produce guidelines for teaching statistics at the college level, referred to as the new guidelines for teaching introductory statistics.
1990's (late) – Increasingly strong call for statistics education to focus more on statistical literacy, reasoning, and thinking. Moore (1997) recommends changes in content pedagogy using active learning and technology for data analysis and simulations.
1999 – The International Research Forums on Statistical Reasoning, Thinking and Literacy (SRTL) begins research studies examining statistical literacy, reasoning and thinking leading to developing learning goals for students at all levels.
2005 – The American Statistical Association endorses two reports for statistics education at the Pre-K to 12, and the other focused on introductory college courses (The GAISE project).
Today – Teaching statistics with technology tools, like *TinkerPlots*®, to represent data and make informal inferences.

Support and Need for Statistics Learning

The widespread use of statistics in our life today has become even more paramount in the 21st century. The ability to collect, organize, describe, display, and interpret data, as well as making decisions and predictions on the basis of that information, are skills that are increasingly important in a society based on technology and communication. Statistics and the use of probability data to help make decisions in business, government, research and everyday life is of uppermost significance. Statistics has become an important tool in the work of many academic disciplines such as medicine, psychology, education, sociology, engineering and physics, just to name a few (Hung 1999).

The study of statistics provides students with the tools and ideas to use in order to react intelligently to quantitative information in the world around them (Garfield & Ben-Zvi, 2007). The NCTM Standards (2000) report the use of statistics in everyday life is staggering and is found in consumer surveys that guide the development and marketing of products, polls helping to determine political-campaign strategies, and experiments used to evaluate the safety and efficacy of new medical treatments. The NCTM report also says statistics are misused to sway public opinion on issues or to misrepresent the quality and effectiveness of commercial products. NCTM believes that students need to understand probability and statistics to become informed citizens and intelligent consumers.

Greer (2000) expresses the importance of statistical education influenced by technological developments as the ratio:

$$\frac{\text{access to data}}{\text{analytical and critical tools for interpretation}}$$

is accelerating out of control. Greer reports most of the statistical information to which the general public is exposed is presented by people with a vested interest to persuade.

Providing students with a methodology for collecting information and facts from multiple sources for conducting research projects and developing survey questionnaires is needed more than ever. This is particularly true in an era where social media traffics fake news websites that publish hoaxes, propaganda, and misinformation (e.g., research findings) readers believe to be true. These fake news sites, over 50 listed on Wikipedia (Wikipedia, 2017), along with use of "clickbait" web content publishing sensationalist headlines or click-thoughts over online social networks influences political views and orientation of personal values.

National Guidelines and Projects for Developing a Statistics Curriculum

Given the development and evolution of the statistics movement toward literacy at all levels, and current widespread use of statistics in society, support for providing a statistics curriculum in schools has been documented. Garfield and Ben-Zvi (2007) report a need to improve students' ability to think statistically with statistical reasoning becoming part of the mainstream school curriculum in many countries. *A National Statement on Mathematics for Australian Schools* (Australian Educational Council, 1991) and *Mathematics in the New Zealand Curriculum* calls for considerable statistics to be taught as part of school mathematics programs, in part to empower students to critically evaluate data and claims made about data.

National calls for increased attention to statistics have been documented providing guidelines for curriculum development. The National Council of Teacher of Mathematics (NCTM, 2000) Data Analysis and Probability Standards report recommends that instructional programs for all students include these three areas related to data and statistical methods, and include the following grade six to eight expectations (refer to Figure 2).

Figure 2. NCTM Data Analysis and Probability Standard for Grades 6-8

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1. **Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them**
    - Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population;
    - Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots.
2. **Select and use appropriate statistical methods to analyze data**
    - Find, use, and interpret measures of center and spread, including mean and interquartile range;
    - Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots.
3. **Develop and evaluate inferences and predictions that are based on data**
    - Use observations about differences between two or more samples to make conjectures about the populations from which the samples were taken;
    - Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit;
    - Use conjectures to formulate new questions and plan new studies to answer them.

(NCTM, Data Analysis and Probability Standard for Grades 6-8, 2000).

The report supports work in data analysis and probability in offering a natural way for students to connect mathematics with other school subjects and with everyday experiences. Similar expectations have been supported by Rutherford and Ahlgren (1990), in the American Association for the Advancement of Science's (AAAS). These authors describe statistics mathematics as a thinking process including the teaching of summarizing data using mean; use of samples and size; and the use of logical reasoning to check the validity of hypotheses for producing conclusions.

The American Statistical Association (ASA) in conjunction with NCTM have supported for years to infuse more exploratory data analysis and elementary statistics into the school curricula. This effort has resulted in the Quantitative Literacy Project (QLP), which included data analysis activities designed for students to interpret real data sets (e.g., tables and graphs) and then create line plots, stem-and-leaf plots, box plots, scatter plots, and calculate or show basic statistics (i.e., median, mean, quartiles and outliers) (Landwehr & Watkins, 1986). These authors report that QLP de-emphasizes use of algebraic formulas for analyzing data. Also included during this reform period has been the Reasoning Under Uncertainty curriculum emphasizing learning by doing, using an interactive graphic software to give students experience with fundamental concepts (Rubin and Rosemary, 1990). The Activity Based Statistics Project focuses on data driven activities using graphic displays (Scheaffer, R., Watkins, A., Witmer, J., & Gnanadesikan, M., 2004).

In the GAISE project (Franklin & Garfield, 2006) report detailed guidelines for developing important ideas of statistics for the pre- to college curriculum, complementing the NCTM standards. These authors describe desired learning goals to help students develop literacy and the ability to think statistically in an introductory course recommending emphasis on developing statistical thinking; using real data; stressing conceptual understanding; promoting active learning; using technology to analyze data; and assessments to improve student learning.

The national calls, organizational support, and project developments have increased attention for statistics instruction, and the need for appropriate curricula for students and teachers. In order to develop a curriculum focused on use of real student data in an active learning context, integrated with technology, it is necessary to examine goals and specific learning skills that will promote statistics literacy.

Student Content Knowledge and Skills for a Statistics Curriculum

To begin examining elements for statistical literacy it is necessary to identify broad goals and reasoning skills students need to acquire as part of an effective curriculum. Next, some specific learning skills and topics that are important for developing student understanding of statistics will be reviewed.

Gal and Garfield (1997) examine the concepts and procedures that are important for students to learn statistics. The authors outline several goals for statistics instruction and these are summarized in Figure 3.

Figure 3. Goals for Statistics Instruction by Gal and Garfield (1997)

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1. **Understand the Purpose and Logic of Statistical Investigations.** As students carry out statistical investigations they need to study and understand the logic behind sampling populations, the notion of error in measurement and inference, and the need to find ways to estimate and control errors.
2. **Understand the Process of Statistical Investigation.** Designing a plan for data collection becoming familiar with the specific phases of statistical inquiry including; formulating a question; planning a study; collecting, organizing and analyzing data; interpreting findings; discussing conclusions and implications from the findings; and evaluating issues for further study.
3. **Master Procedural Skills.** Mastering statistical investigation skills involving organizing data; computing needed indices (e.g., median, average, and confidence interval); and construct and display useful tables, graphs, plots, and charts, manually or assisted by technology.
4. **Understand Mathematical Relationships.** Developing intuitive and formal understanding of statistical displays (e.g., graphs), procedures and concepts. For example, explain how the mean is influenced by extreme values in a data set.
5. **Develop Interpretive Skills and Statistical Literacy.** Students need to interpret results and develop awareness of possible biases or limitations on the generalizations that can be drawn from data used in statistical investigations. Learning how to interpret results to pose critical and reflective questions about the data findings is needed.
6. **Develop Ability to Communicate Statistically.** Communicating effectively using appropriate terminology to present results of statistical investigations. Students also need to convey results in a

convincing way, construct reasonable arguments based on data or observations, and develop skills to be able to challenge the validity of other people's statistical investigations or generalizations made on the basis of a single study of a small sample.

These authors report these broad goals help students develop statistical reasoning skills in an information-laden society. They also believe it is helpful to delineate some specific types of reasoning students need to develop as they learn statistics in the elementary and secondary school. These specific types of statistical reasoning are summarized as follows:

1. **Reasoning about data:** Knowing how the type of data (e.g., quantitative or qualitative) leads to a particular type of table, graph or statistical measure.
2. **Reasoning about representations of data:** Understanding how to read and interpret graphs; modify graphs; and recognize shape, center and spread.
3. **Reasoning about statistical measures:** Knowing predictions for large samples will be more accurate than for small samples; and understanding measures of center, spread and position about a data set.
4. **Reasoning with samples:** Understanding how samples are related to populations and what can be inferred from a sample or cautious when making inferences made on small or biased samples.
5. **Reasoning about association:** Knowing how to judge and interpret a relationship between two variables and that a strong correlation between two variables does not mean that one causes the other.

Gal and Garfield provide these guidelines for instruction in statistics education, along with the types of statistical reasoning needed for students to learn.

Chance and Rossman (2001) discuss some general propositions and topics students should learn in statistics. According to these authors, students need to know how to formulate a question before collecting data. Chance and Rossman report that by starting with the question and deciding what data will best address it, students learn the tools and good habits of statistical thinking in a logical order. Ideas of data collection should also be taught at the early stage to include concepts of bias, precision, representative samples, and legitimacy of conclusions. These authors also suggest the following topics should emerge including data production issues with regard to measurement, sampling and experimentation; introducing and revisiting fundamental ideas (i.e., variability, relationships between variables, and reasoning of inference); emphasizing common elements of analysis that arise in different situations (e.g., progress from graphical displays to numerical summaries); providing technology and simulations; and understanding sampling distributions as crucial for understanding concepts of inference.

Broad goals, reasoning skills, general propositions, and topics needing emphasis for an effective statistical literacy program for students have been presented. Support and direction for teaching statistics suggests one way to help students value statistics may be to embed statistics within other disciplines (Garfield & Ahlgren, 1988; Rutherford & Ahlgren, 1990). Greer (2000) reports as statistics has entered school curricula in countries across the world, it has been primarily located within mathematics, with considerable debate as to whether statistics is part of mathematics or considered a liberal art. Identifying appropriate learning skills and topics for an integrated statistics curriculum provides a foundation for curriculum developers, however, it is necessary to also examine common student misconceptions in statistical understanding to target areas for providing teacher scaffolding and support.

Student Statistical Thinking and Learning

Student learning issues and conceptions in achieving statistical literacy is documented in the literature. Awareness of these issues is important for the teacher in order to know when to provide instructional scaffolding to change students' beliefs and intuitions about statistical phenomena. Awareness of student thinking about samples, aggregate data, graph analysis, distributional reasoning from the population, variability, measures of center, fair testing, and other statistical ideas will improve the development and implementation of an effective statistics curriculum. Intervention strategies are emerging in the literature to support student conceptual development of statistical concepts along with developing conclusions based on inferences drawn from the data. Variation is a foundation of statistics providing the basis from which inferences can be drawn during statistical decision making (Watson & Wright, 2008). Much of the more recent research supports the use of technology, like *TinkerPlots*®, to assist students in interpreting their graphed "data plots" and to draw inferences. Makar (2013) describes inferring as follows:

> Informal statistical inference uses data to make predictions or conclusion about an uncertain event. An inference must be stated with uncertainty because the exact answer is not known for sure, but can only be estimated. (Makar, 35, 2013).

Makar reports describing data and inferring beyond data are at the core of statistics. In this section of the paper discussion of statistical conceptual thinking of students and inference will be presented along with emerging strategies to support learning.

Graphing Skills, Distributions, and Average

A number of researchers have reported students having poor graphical interpretation skills and are often unable to reason beyond graphs making connections between the context and the data. Student difficulties when reading and interpreting particular types of graphs, is reported in the literature (Shaughnessy, 2007). Yingkang (2004) study investigated 13 to 15 year old students' ability to read, interpret, construct and evaluate statistical graphs concurrently and found teachers should assist students to correct graph convention errors, help them develop problem solving abilities in statistical graphs, advice them to properly use their contextual knowledge to solve a graph related problem, and guide them to communicate mathematical ideas clearly. Friel et al. (2001) identified three main components for graph comprehension, based on a synthesis of information, involving:

1. The ability to read information directly from a graph based on understanding of the conventions of graph design
2. Manipulating information read from a graph by making comparisons and computations
3. Relating the information in the graph to the context of the situation to generalize, predict, or identify trends.

These authors report research on understanding what makes these three main components difficult for graph readers is needed. Friel et al. report teachers need to consider the instructional sequencing for learning types of graphs, develop understanding of data reduction (e.g., compiling data to discover or create fewer categories), and apply various aspects of graph sense (i.e., creating graphs in a variety of problem contexts).

Some research has been provided addressing appropriate types of graphs for student learning. Carr and Begg (1994) introducing box plots to 11- and 12- year-old students observational study found box-plots are an appropriate topic for students in this age group provided that teachers emphasize the understanding and interpretation of the plots, and not just the construction. However, Bakker et al. (2004) reported delaying the introduction of histograms and box-plots due to the difficulties that middle school students have with proportional reasoning (i.e., quartiles) that is required to interpret these two types of graphs. In a report by Watson (2012a) it is suggested that for students who are struggling in understanding box plots or younger students needing more basic representation there is the hat plot provided in *TinkerPlots*®. Watson (2012b) describes the use of *TinkerPlots*® with Autralian middle schoool students learning the idea of resampling to determine how unusual the difference (e.g., medians) is between to groups. A Sampler tool with the program using *Reaction_Time* randomly collects samples without replacement allowing students to create a History of Results and then graphs comparing differences in reaction time.

Duncan and Fitzallen (2013) suggest an earlier introduction, comparing student time trials in completing a maze activity, to student learning box plots using *TinkerPlots*® given experiences using multiple forms of data representation (i.e., intrepreting column graphs, dot plots, stem-and-leaf displays, and histograms). These authors report the benefits of using box plots and scatter plots earlier in the curriculum, in providing students time to develop exploratory data analysis strategies and fundamental intuitions about working with data before focusing on formal statistical interpretations.

Fitzallen (2013) studied student understanding of graph skills when constructing plots using *TinkerPlots*® suggesting the active role of teacher scaffolding in supporting student graph development and data analysis. Fitzallen studied learning strategies of 12 11-12 year old primary school aged Australian students, over a six week period, using *TinkerPlots*® to construct graphical representations. Fitzallen found that students displayed three dominant strategies when working in pairs through a sequence of learning experiences that introduced elements of *TinkerPlots*® for graph creation and data analysis, as well as the fundamentals of graph intrepretation:

1. **Snatch and Grab:** Students accessed elements in a random manner and had incomplete knowledge about the potential of the program to support data analysis activities.

2. **Proceed and Faltar:** Students used the program purposefully as a construction tool creating graphs with confidence, but often made responses indicating why the respresntations were useful.
3. **Explore and Complete**: Students effectively used the program to support the interpreation of graphs with question responses and graph descriptions conveying intuitions developed about graphing shaped by the data representations.

Fitzallen reports the three strategies show the different ways students worked within the *TinkerPlots®* learning environment and have implications on the active role of the teacher in establishing and supporting the development of student thinking and learning. The study found that having an understanding of how students use interactive software would inform teachers about when to and in what ways to intervene in the learning process.

Further understanding of student graphing interpretations related to data distributions and average using *TinkerPlots®* is discussed by Konold (1989). Konold found students making decisions about single events rather than looking at a series of events. This idea was substantiated later by Konold, Higgins, Russell and Khalil (2004) in a case study of elementary students understanding of data using data analysis software. These authors found that rarely did these students interpret data from an aggregate perspective (e.g., What does this graph show?). Konold et al. (2004) analysis of learning identified four general perspectives that students use when interpreting tool technology data as pointers, case values, classifiers and as an aggregate. Konold found some students are inclined to view data from one particular perspective, which influences and perhaps constrains the types of questions they ask, the plots they generate or prefer, the interpretations they give to notions such as the average, and the conclusions they draw from the data. These authors report the aggregate perspective involves being able to understand and view a complete set of data in unifying with emergent properties such as shape and center. For example, students can understand the concept of average as a label given to a single case or subset, but not as a measure that applies to the entire group. These authors report that students go through acceptable stages in their understanding of statistical data, and that by helping them focus on the values of individual cases in data set students can stay connected to the meaning of the data. Other researchers have reported student misconceptions involving computing averages without focusing on outliers or understanding sampling procedures taken from a larger population (Garfield & Ahlgren, 1988; Shaughnessy, 2007). This research suggests the active role of the teacher will be necessary to support and scaffold student development and understanding of their graphs.

Further research on specific age appropriate types of graphs to facilitate student learning and understanding will be needed, particularily used with technology tools like *TinkerPlots®* or other adaptable software programs, since graphs are critical to evaluating data and developing statistical thinking, reasoning, and literacy. In addition, how teacher scaffolding can support student learning in creating and evaluating graphs will be necessary when using these computer software tools.

Sample Distributions from the Population, Variability, and Central Tendencies

Insight into prevalent ways of student thinking about statistical samples is discussed in the literature. Kahneman, Slivic and Tversky (1982) found student misconceptions when estimating the likelihood, a sample represents or resembles the population. These authors report that errors in reasoning were found in understanding of small samples. Misconceptions were found when beliefs included that small samples should resemble the populations from which they are sampled; so small samples are used as a basis for inference and generalizations. Shaughnessy (2007) reviews of the literature reports students make judgmental errors based on occurrences with neglect to sample size. Misconceptions identified include egocentric impressions of frequency of events biased or based on single occurrences of an event taking on inflated significance when it happens to the person. For example, judgment of likely or unlikely coincidences, subjects thought their own coincidences (i.e., bumping into a friend in a foreign country) were more surprising than coincidences that happen to others. Watson and Moritz's (2000a) survey and follow-up interview study of 11-15-year-old students recognition of newspaper bias found teachers' need to help students become aware of potential sources of bias in sampling, and appreciate the importance of variation in samples and populations.

Distributional student reasoning involving making connections from the populations to samples and averages is presented in the literature. Students' spectrum of intuitive reasoning has been documented in which at one end their thinking is focused on centers and a belief that all samples should be perfectly representative, and the other end too focused on variability with all the possibilities for individual outcomes over or under estimated (Konold, 1989; Rubin, Bruce, & Tenney, 1991). In order for students to reason about distributions and grow beyond a mere focus on expectation, they must develop their intuition for a reasonable amount of variation around an expected value, not just the expected value itself (Shaughnessy, Ciancetta, & Canada, 2003). English and Watson (2015) conducted a longitudinal study of grade four elementary students understanding of variation. Imploying an arm measurment activity evaluation of hand-drawn and *TinkerPlots®* generated representations these authors found that over half (n=115) of the students had developed the ability to transfer and explain the meaning of variation and could detect distribution differences.

The need for student understanding going beyond averaging and comparing data sets to developing conceptual understanding about variability or shape and spread of data has been recommended (Wild & Pfannkuch, 1999; Konold & Pollatsek, 2002; Shaughnessy, 2007). Shaughnessey (2007) reports within the field of statistics variability arises in data, samples, and distributions and students need to develop their intuition for what is a reasonable or an unreasonable amount of variability in these objects. Shaughnessy & Pfannkuch (2002) report students' rush to compute a mean and base prediction on measures of central tendency without even considering what the variability in a data set might reveal about the context.

Support for students to learn and understand central tendencies about data has been reported. This has included measures of center, mode, median and mean, as summary statistics used for a variety of purposes, including helping to describe and analyze data. Friel (1998) reports students need to understand what each of these measures tells about a set of data, and make judgments about when and why to use each measure. Friel recommends students need to analyze one or more sets of data, and be comfortable in knowing how and why they carry out the actual algorithms. According to Friel, understanding develops over time with increasing sophistication when students engage in various problems in a number of different contexts. Students move from conceptual to procedural understanding, able to use the necessary algorithms and to focus their attention on the interpretations of their results based on their understandings of what they know about data given various statistics and representations (Friel, 216, 1998). Watson & Moritz (2000b) interview research study of elementary and middle school students recommend that the teaching of average should build up from students' initial preferences for "middles" and "mosts" to the more normative conception of mean as representative of a data set.

More research and intervention strategies will be needed to support student understanding of population sampling and variability in a data set. This will also include learning opportunities in understanding central tendencies about the data to adequately interpret their authenic project work.

Drawing Conclustions and Questions to Predict Informal Statistical Inference

Students evaluate their data set of information gathered in a research project in order to write conclusions about the findings. As they describe data, based on graphed interpretations, they attempt in developing additional questions making inferences generalized to a larger population. Student generalizations about their research project demonstrate informal inference thinking. Discussion by researchers is presented discussing interventions and methods to promote student prediction skills in developing informal statistical inference.

Watson and Moritz (1999) interview study of 88 Austrailian students in grades 3 to 9 required students to compare the performance of two classes on a test. These authors report the importance of using comparison of data sets to build early experiences in learning statistical inference has not been overlooked for classroom use. For examples curriculum for elementary schools have included activities comparing student shoe sizes, heights of first and fourth graders, paper clip blowing game outcomes, and sugar content in cereals. For older students' investigations have included comparing of of newspaper sentence length, determining if practice improves estimating skills, evaluating sports teams and using starter questions (e.g., Do children eat more sweets than adults?) in the context of describing data, generalizing or making predictions. These authors found students used numerical and visual strategies, either individually or in conjunction with each other, to make comparisons between the data sets presented in graphs. Watson and Moritz report both numerical and visual strategies have their place in statistical analysis and it is important for teachers to encourage using each to reinforce an initial judgement based on the other or point out where one may be more appropriate for use than the other. In this study student use of statistical mean for comparison was used on a limited basis, rather than the visual strategy, when comparing groups. These authors report this may suggest that mean should be introduced later at the elementary level to develop a deeper understanding of the concept and its applications.

Ben-Zvi (2006) describes use of *TinkerPlots®* with teacher scaffolding involving students collecting data about themselves and peer students compared to a UK Census at School database. Ben-Zvi found, based on pre-post tests, significant improvements in students' understanding of informal inference and developing knowledge of statistical ideas. This was supported by Watson's (2008) study of informal inference using box plots with grade 7 students finding evidence of change on the part of students' appreciation of decision making with data, as well as the potential for *TinkerPlots®* to assist in the process.

In a study of third-grader in Cyprus inferential reasoning Paparistodemou and Meletiou-Mavrotheris (2008) found students were able to express informal inference generalized to a larger population. This was achieved by student authenic developed projects (i.e., questionnaires on health) along with utilization of *TinkerPlots*® supporting scaffolding and extending children's informal statistical reasoning. A later study supporting students understanding of sampling representation and variability to make valid inferences regarding population characteristics is provided by Meletiou-Mavrotheris and Paparistodemou (2014) study. The study implemented a three-phase inquiry-based learning environment (i.e., referred to as a hypothetical learning trajectory or HLT) in a Cyprus grade 6 classroom, which included a student developed research study collecting data through a survey sample with analysis using *TinkerPlots*®. The authors reported the class as a whole showed, by the end of the experiment, improved understanding of sample size, potential sources of bias due to sampling design, legitimacy for simple random sampling, and sample stratification as a means for increasing sampling representativeness for some population attributes. According to Meletiou-Mavrotheris and Paparistodemou, when given the chance to participate in an appropriate instructional setting (i.e., HLT learning context and conducting a study on a topic of interest) students can exhibit well-established understandings of sampling issues and other fundamental concepts related to statistical inference.

Based on their review of the literature Garfield, Le, Zieffler, and Ben-Zvi (2015) suggests providing project-based learning with authentic data problems requiring student metacognition and using dynamic data investigation tools. These authors suggest informal learning approaches in early elementary education include approaches such as "growing a sample" activities and utilizing innovative technology like *TinkerPlots*®. Ben-Zvi, Bakker, and Makar (2015) describe "growing a sample" as an approach where students are gradually introduced to increasing sample sizes taken from the same population and asked to make an informal inference for each sample. Watson and Wright (2008) suggest building informal inference with *TinkerPlots*® in a measurement context with students in grades 6 to 10 through investigation activities using a research procedure involving setting the question, collecting data, representing data with *TinkerPlots*®, summarizing data, discussion of sampling questions (i.e., ways to randomly choose a sample) and drawing conclusions. Extension investigations are also provided comparing measurements on two groups and on two variables.

Makar (2013) reports informal teaching of inference can be taught to middle school students when designing learning environments through a "bottom-up" approach taking into account not only what students need to learn, but also their everyday experiences with prediction and inference. Makar describes middle school classroom investigation teaching students about making inferences from data about flight. In this investigation students had to collect data on five flights for a simple loopy plane (i.e., straw and paper strips) measuring the distance for the best design. Using *TinkerPlots*® to record the data from flights, for each student plane in the classroom, conclusions were made on which designs had the longest measured flight. Makar suggests other statistical inquiry questions to promote learning of informal inference in the report.

Watson and Donne (2009) study explored the use of *TinkerPlots*® when interviewing, observing, and collecting work samples of students aged 11-14 years about their approaches to beginning inference. The study used a ptotocol, comparing the *TinkerPlots*® group with paper-based graphs associated with inference in the Watson and Moritz (1999) study. Watson and Donne (2009) found the *TinkerPlots*® format was more efficient for exploring students' understanding of finding evidence for associations (comparisons) of variables and beneficial in providing flexibility for students to display their understanding. Based on their study these authors recommend opportunity for classroom discussion if students are allowed to create their own plots and then share them with each other and state:

> Interpreting each others' plots would be excellent experience for both the
> reader and the creator of plots (Watson and Donne, 31, 2009).

According to Watson and Donne, a report supplementing the plots with text boxes include observations, suggestions, and hypotheses based on data set findings. It is also recommended that a check list be used at the beginning of the studies interviewing students to assess which *TinkerPlots*® tools are familiar to the student and which are not.

Ben-Zvi, Bakker, and Makar (2015) report on studies regarding students' understanding of samples and sampling when making informal statistical inferences and instructional approaches to promote understanding of statistical inference. Based on these studies these authors support authentic experiences in collecting data through survey and experiences using simulation tools (e.g., *TinkerPlots*®) to help students develop understanding of sampling and informal inference.

The following topics have been discussed to develop student statistical literacy including graphing data to interpret distributions and central tendencies; sampling and variability from the population; and drawing conclustions for predicting informal statistical inference. Use of statistical software-based programs like *TinkerPlots*® provides support to students to evaluate data set findings and make inferences. Khairiree and Kurusatian (2009) found *TinkerPlots*®, if appropriately employed as a problem-based learning tool, can be effective in enhancing active learning and students' understanding of statistics.

Other more fundamental mathematical conceptual literacy considerations will need to be considered and discussed by Garfield and Ben-Zvi (2007). These authors report students have difficulty with many statistical ideas and complex rules underlying mathematics (e.g., fractions, decimals, proportional reasoning, and algebraic formula) that interfere with learning related statistical concepts. According to Garfield and Ben-Zvi, the content of statistical problems causes faulty intuitions rather than using data-based evidence, and students feel uncomfortable with the "messiness of data" creating different possible interpretations. Attention to students' statistical conceptions and beliefs will be necessary, since research is showing many teachers unconsciously possess a variety of misconceptions that might be shared with students (Rubin & Rosebery, 1990; Makar & Confrey, 2004).

Providing Teacher Support for Implementing a Statistics Curriculum

Teacher Conceptual Understanding and Attitudes

Teacher's poor understanding of the content, concepts, and ideas about statistics, along with methodology issues is problematic for teachers (Garfield & Ahlgren, 1988; Russel, 1990; Hawkins et al., 1992). Teachers need support at several levels to effectively implement a statistics curriculum for students. The literature review examines teacher attitudes and beliefs toward statistics teaching, the need and areas for training, elements for providing curriculum support, curriculum delivery considerations, and use of *TinkerPlots*® technology for staff development.

Attitudes and beliefs are important considerations for preparing teachers to teach statistics. There is considerable research to indicate that teacher attitudes about mathematics influence their learning and teaching of mathematics (Nespor, 1987; Thompson, 1992; Richardson, 1996; Hart 2002). Ball states that people's understandings of mathematics are interrelated with how they feel about themselves and about mathematics (Ball, 461, 1990). Battista (1986) study found that learning a mathematical pedagogy could reduce the mathematics anxiety of preservice elementary teachers. Nespor's presentation of the model of beliefs suggests if we are interested in why teachers organize and run classrooms as they do we must pay much more attention to the goals they pursue (which may be multiple, conflicting, and not at all related to optimizing student learning) and to their subjective interpretations of classroom processes (Nespor, 325, 1987). Thompson states research on teachers' beliefs has made clearer to us that no simple model of teaching and learning can be used to account for teachers' and students' actions in the classroom (Thompson, 142, 1992).

Mills (2008) survey study of elementary and secondary teachers' attitudes about statistics found grade 6-8 teachers reported being more comfortable teaching statistics than P-K teachers, and slightly more comfortable than grade 1-5 teachers. Mills also found teachers who agreed that they like teaching statistics, and are more comfortable doing so, had more experience with statistics training. This study indicates that how much statistics experience a teacher has had probably affects their attitudes and perceptions. Mills reports the most important implication for educators is that teachers reported they need additional training, and that they have difficulties understanding statistics concepts. Some of the major topics teachers reported least comfortable in teaching included probabilities, standard deviation, word problems, hypothesis testing, and correlation. Mills states that most teachers reported that developing and evaluating inferences and predictions that are based on data was the most difficult to implement (Mills 6, 2008).

The need for a curriculum model and methodology that provides adequate support for teachers is discussed in the literature. Hawkins, Jolliffe and Glickman (1992) survey of UK teachers report most respondents enjoyed teaching probability and statistics, but found that a scientific methodology was needed when data is evaluated and processed. Russell (1990) found a stumbling block for teachers using an elementary number collecting and analyzing real data number program was the lack of confidence and knowledge about the procedures and problems they gave their students. Russell reports there are few models or experiences for teachers to draw on for collecting, representing, or describing a particular set of data. Russell says it is difficult for teachers to change the way they teach math without models, images and experiences to guide them. Another problem area identified by Russell is teachers' inability to recognize and respond to students' solutions and interpretations.

Teachers feel uncomfortable teaching statistics concepts because they have not been adequately trained, and many of the teachers have either never taken a formal statistics course or had very little formal training (Begg & Edwards, 1999; Franklin, 2000). Groth and Bergner (2006) studied preservice elementary teachers' conceptual and procedural knowledge of mean, median, and mode. These authors found a majority of teachers exhibited limited understanding displaying syntactic and algorithmic procedural knowledge with concepts interferring with attaining concepetual understanding.

Professional development activities are probably the most important resource for teachers to improve meaningful knowledge of content and attitudes toward mathematics (Battista, 1986; Ball, 1991; Hill & Ball, 2004; Quinn, 1997). Schoen, Cebulla, Finn, and Fi (2003) found similar results, and that completion of a professional development math workshop course was positively related to growth in student achievement. Watson (2001) use of an information profile to assess the need for professional development found teachers' lack confidence in statistics and lacked knowledge about sampling. These teachers also reported needing professional development in data and chance.

Intervention Strategies to Support Training

Ideas addressing the most appropriate context for delivery of a statistics curriculum, along with providing a stochastic learning environment, are suggested. A consideration in teaching data analysis reflects the differences between mathematics and statistics, and how statistics is a separate discipline. Support for describing statistics as a separate discipline from mathematics as a science through gaining insight from the context of data and requiring use of different types of reasoning is documented (Rossman, Chance & Medina, 2006; Cobb & Moore, 1997; delMas, 2004). Implications for this difference suggest experiences in the statistics classroom focusing more on stochastic processes and ideas rather than computations and procedures; students experiencing first hand the process of data collection and exploration; and including experiences promoting discussion on how data is produced with selection of appropriate statistical summaries to support drawn conclusions (Landwehr & Watkins, 1986; Friel, 1998; Moore, 1998; delMas, 2004; Rossman, Chance, & Medina, 2006). The separate discipline argument with regard to teaching methodology was found in an experiment to assess new strategies for teaching statistics at the secondary level in Italy, in which Gattuso (2002) reports teachers trained in mathematics taught statistics using a mathematical approach rather than as a teaching style appropriate to statistics. Statistics is much more closely related then mathematics to other sciences (i.e., linguists or geography to physics, engineering or economy) where it is used as the language and method of scientific inquiry, and from which many statistical methods were developed (Franklin & Newborn, 3-4, 2006). In a similar position Starkings (1993) suggests that issues relating to the teaching of data analysis are important to teachers of a wide range of subjects across the whole curriculum. In most educational establishments data analysis does not exist as a subject in its own right (Starkings, 104, 1993).

Staff development for teacher use of technology tools, like the *TinkerPlots* program, is needed. Hammerman and Rubin (2003) worked with middle school and secondary school teachers creating *TinkerPlots*® bin graphs to compare different groups. Teachers found many ways to work with the variability of data to make it more manageable. Hall (2009) describes a teacher hands-on exploration workshop using *TinkerPlots*® where participants used real data about their pupils that resulted in positive attitudes toward teaching statistics.

Effective staff development programs will be needed to improve teachers' content knowledge of statistics, address teachers' beliefs and attitudes toward the subject, support use and implementation of a stochastics curriculum, and provide training in the use of technology tools. Training to develop teacher's conceptual understanding of statistics will be necessary as reported by Rubin and Rosebery (1990) suggesting finding teacher's prior notions of statistical concepts that can actually interfere with acquiring a more sophisticated understanding of even basic concepts like median. In addition, teachers will also need training supporting students' not only with statistical techniques, concepts and tools but also with the many nuances, considerations and points of view involved in generating, describing, analyzing and interpreting data and in reporting findings (Ben-Zvi, 2001). Friel et al. (2001) report teachers will also need to increase their knowledge about different types of graphs and learn how to teach graphing skills. According to Rubin and Rosebery (1990) for teachers to gain expertise in statistical reasoning they have to experience "being statisticians" themselves. These authors suggest teachers investigate statistical problems that interest them, collect data, analyze, and draw conclusions the way statisticians would. More research will be needed to evaluate these variables specifically related to providing effective teacher training in statistics to ultimately facilitate students' development of statistical literacy.

Given current information about students' statistical thinking and study of student learning opportunities, supported with technology tools like *TinkerPlots*®, a framework for teacher planning learning goals and designing learning tasks will need to be developed. A framework that is capable of predicting the kind of learning and thinking that will occur as tasks are played out would be most helpful. Mooney's (2002) qualitiative study of students across grades 6 – 8 developing and validating a framework for characterizing students' thinking across four processes: describing data, organizing and reducing data, representing data, and analyzing and interpreting data may serve as a starting point. Providing specific student skill intervention strategies for each process on the framework, based on current research best practices, would have implications for instruction and curriculum design related to learning statistical data analysis.

Supporting teachers in creating a stochastic classroom for students integrating the teaching of statistics using technology tools across the curriculum will require staff development training. The training will need to not only improve teachers' content knowledge of statistics, including the use of technology tools, but also address their attitudes and perceptions about the subject. Specific intervention strategies using teacher scaffolding will need to be provided as students evaluate their data using tools like *TinkerPlots*® to make conclusions and draw inferences.

Is *the Survey Toolkit* Curriculum a Paradigm Fit?

The Survey Toolkit curriculum and *TinkerPlots*® software have been used by the author to provide instruction to students in learning about survey and statistics when teaching grade six high ability students receiving services in the Extended Learning Program (ELP). ELP extends and differentiates the existing grade level curriculum to provide a more challenging and rigorous learning experience for students.
The literature review presented provided support for statistics literacy for all students and teachers. Information was presented to provide the teaching of data analysis across the curriculum (Starkings 1993, Gattuso 2002, Franklin & Newborn, 2006). Numerous authors reported support for teaching statistics to younger students using authenic project-based learning with teacher scaffolding (Ben-Zvi, 2006; Makar, 2013; Paparistodemou & Meletiou-Mavrotheris, 2008; Meletiou-Mavrotheris & Paparistodemou, 2014; Garfield, Le, Zieffler & Ben-Zvi, 2015; Ben-Zvi, Bakker & Makar, 2015). Use of technology tools using *TinkerPlots*® for students to develop graphs and compare data plots in order to draw conclusion and make inferences was presented (Konold, Higgins, Russell & Khalil, 2004; Ben-Zvi, 2006; Watson, 2008; Watson & Wright, 2008; Watson & Donne, 2009; Khairiree & Kurusatian, 2009; Watson, 2012; Duncan & Fitzallen, 2013; Meletiou-Mavrotheris & Paparistodemou, 2014; Garfield, Le, Zieffler & Ben-Zvi, 2015; Ben-Zvi, Bakker & Makar, 2015), along with providing staff development to teachers (Hammerman & Rubin, 2003).

Implementation by the author in using the *The Survey Toolkit* and *TinkerPlots*® with grade six students for fives years, with over 100 students, has resulted in development of poster display projects on numerous topics (refer to Figure 4) based on their interests. Given support in the

Figure 4. Research Question Topic Ideas Selected by Middle School Students (Author, 8, 2011)

Science and Technology	**History and World Cultures**
Aircraft	Ancient China
Aviation Progression	Ancient Egyptian Cultures
Alternative Fuels	Ancient Egyptian Gods and Goddesses
Astronomy	Ancient India
Constellations	Confucianism and Taoism
Flying Devices	Easter Island
Energy and Machines	Egyptian Mythology
Energy Sources (Forms)	Famous People of Medieval Times
"Green" Environment	Foods of the Renaissance
Hovercrafts and Segways	Greece / Greek Mythology (Gods)
Inventions	Rome
Light Reflection and Sound Waves	Han Dynasty
Math and What People Like About It	Hinduism
NASA: The Founding and Space Pilots	History of the Renaissance
Nanotechnology	Medieval Music
Natural Disasters	Medieval Period and Castles
Physics: Work, Energy and Power	Medieval Siege Weapons and Castle Defenses
Planets	Roman Infantry
Rockets	Spartan's Weapons
Simple Machines	Travel Destinations

Solar Energy	Tudor Dynasty
Space Exploration	**Health, Psychology, and Nutrition**
Technology Advances	Brain and Hemispheres
Virtual Reality Machines	Brain and Nervous System
Volcanoes	Eyes and Vision (Ophthalmology)
Weather	Healthy Choices
	Nutrition and Exercise
	How Color Affects People (Mood)

literature for student authenic project-based learning on topics of interest using "real data," use of this curriculum, partially or in its entirety, may serve as a viable option for educators.

The Survey Toolkit Curriculum Integration with *TinkerPlots*®

This instructional program is a project-oriented learning curriculum on research methods developed primarily for elementary to middle school age students based on study of research instructional design methodology at Iowa State University. The program has been field-tested with the author's regular grade three students and grade six gifted education students for over 10 years. The research method was found effective in guiding students in choosing a research question, writing a research report using a cluster paragraph information collection strategy, developing unbiased questions for giving a survey to a reliable sample, analyzing survey data using *TinkerPlots*, and sharing results on presentation boards. *The Survey Toolkit* curriculum was found to be applicable for researching topics across the curriculum.

The Survey Toolkit lessons and activities follow research sequence students follow to successfully complete a survey project. The text was organized based on the scientific method and follow a research methodology supported by Borg and Gall (1989). These texts provide a methodology for students and teachers to follow for developing a survey research project using *TinkerPlots*®, and are described in Figure 5. *TinkerPlots*® is a tool technology in which students enter survey data into data cards and create graphs to analyze and show findings from their research study, which provide support in writing a final report with a conclusion and inferential

Figure 5. The Survey Toolkit Lessons Plans and Activities Listed in the Table of Contents

Part 1. Choosing a Research Question
- 1.1 Introducing Surveys
- 1.2 Looking at Survey Data
- 1.3 Planning and Setting Goals
- 1.4 Finding Information
- 1.5 Summarizing Information

Part 2. Developing and Giving the Survey
- 2.1 Writing Survey Questions
- 2.2 Choosing a Sample
- 2.3 Writing a Hypothesis
- 2.4 Finishing and Giving the Survey

Part 3. Analyzing Survey Data
- 3.1 Representing Survey Responses
- 3.2 Entering Data into TinkerPlots
- 3.3 Exploring Categorical Attributes
- 3.4 Exploring Quantitative Attributes
- 3.5 Comparing Attributes

Part 4. Sharing Results
- 4.1 Writing Findings and Conclusions
- 4.2 Summarizing Your Research
- 4.3 Making a Poster or TinkerPlots Report
- 4.4 Writing a Report (Author, 4-5, 2011).

questionning. Refer to Author (2011) *Journal of Statistics Education* (JSE) article for further information about the development, implementation, and use of the curriculum with students. The survey curriculum program is available as follows:

- *The Survey Toolkit* is available by contacting MHE by email @ orders_mhe@mheducation.com and providing the ISBN #978-1-55953-886-2.
- *TinkerPlots* is available at the University of Massachusettes for ordering @ http://www.srri.umass.edu/tinkerplots/.

The Survey Toolkit Resource Manual is an unpublished manuscript used with the author's students to support and provide background reading and activities for *The Survey Toolkit* text. The manual includes additional activities and materials to support delivery of the curriculum. The readings provide students with additional information about key concepts and vocabulary involved in conducting survey research. The manual includes a staff development plan for *The Survey Toolkit* and *TinkerPlots*® teacher training. Student project examples are shown to provide additional conceptual understanding. The resources are available for use at the JSE website. Click on the link below to download the 88 page *The Survey Toolkit Resource Manual.*

http://www.amstat.org/publications/jse/v19n1/SurveyToolkitResourceManual2011.pdf

The literature review link, published in the JSE publication, is not longer active since the information is provided with this journal report publication.

Implications of a Statistics Curriculum and Further Research Directions

Given support for an authenic learning experiences for students in learning statistics using curriculums like *The Survey Toolkit*, the literature review presents further questions regarding how to address student learning issues and supporting teachers in implementation of a statistics curriculum. Given a curriculum using *The Survey Toolkit* with *TinkerPlots*® for developing project-based learning, teacher scaffolding support will be necessary for student success in:

- Constructing appropriate plot graphs of collected data (e.g., When should students create a box plot?),
- Creating graphs from an aggregate perspective to evaluate inference,
- Evaluating data plots, which support student research questions for writing conclusions,
- Increasing awareness of potential sources of bias in sampling,
- Appreciating and understanding the importance of variation in samples and populations.

Support to successfully guide student learning will be required for teachers in the following ways:

- Understanding of the content, concepts, and ideas about statistics, along with methodology curriculum issues
- Addressing attitudes, beliefs, and comfort level for preparing teachers to teach statistics,
- Training teacher use of technology tools, like the *TinkerPlots* program,
- Creating a stochastic classroom to recognize and respond to students' solutions and data plot interpretations.
- Integrating the teaching of statistics project work across the curriculum or among teacher teams providing instruction in different subject areas.

Supporting teachers in creating a stochastic classroom for students integrating the teaching of statistics using technology tools across the curriculum will require staff development training.
Effective staff development programs will be needed to improve teachers' content knowledge of statistics, address teachers' beliefs and attitudes toward the subject, support use and implementation of a student developed research project, and provide training in the use of technology tools.

Further research investigations have reported goals and specific learning skills for instruction in statistics education. These propositions and topics students should learn have provided some guidelines for developing an effective statistics literacy program. More recent research addressing student misconceptions in statistical thinking and pedagogy issues, including use of technology tools like *TinkerPlots*®, suggests areas in the curriculum where teacher scaffolding will be necessary to support student learning. Teachers' attitudes and understanding of concepts indicates the need for appropriate staff development experiences for successful implementation of a statistics curriculum using data generating tool programs like *TinkerPlots*®.

According to (Ben-Zvi, Bakker, and Makar (2015) that despite the emergence of innovative learning environment and curricula there is still not enough research on the ways it can be used to support the emergence of students' statistical reasoning effectively and efficiently and how to assess them. We also do not know much about teachers' understanding of these issues or how they can assist their students in developing these ideas.

Given resources like the *The Survey Toolkit* and resource nanual, providing a written narrative of data analysis concepts along with student examples, will need to be evaluated in developing student understanding of concepts and teacher attitudes in implementing this type of stochastic curriculum. The staff development plan and use of the manual with teachers will also need to be studied to determine if this resource promotes implementation of an effective statistics curriculum. In addition, do the lesson plans and student activities in *The Survey Toolkit* provide adequate teacher support and scaffolding to promote student understanding of critical concepts and skills, including use of *TinkerPlots*®? Finally, further research and effective use of technology tools like *TinkerPlots*® with students and teachers will also need to be explored as it is used in this curriculum context.

CONCLUSION

The study of probability and data analysis is historically rooted emerging out of other disciplines leading to support from NCTM and other organizations. These organizations and projects have lead to development of a movement supporting a statistics curriculum in the schools with literacy at all levels. A historical perspective in the development of statistics education as a discipline leading to the need for statistical literacy at all levels in a technology-based society was presented. Support and need for statistics learning due to widespread use, influence of technology development and social media used to persuade public opinion and traffic fake news was discussed. National guidelines and projects for developing a statistics curriculum were examined.

Student content knowledge and skills including important topics for study in teaching a statistics curriculum was provided, along with student learning considerations. Use of technology tools, like *TinkerPlots*®, for student use in promoting informal inference was presented providing insight into effective learning practices and support using teacher scaffolding. Teachers' attitude about teaching statistics along with pedagogy issues, including the need to provide staff development using *TinkerPlots*®, was explored.

Consideration of *The Survey Toolkit* currriculum using *TinkerPlots*® was evaluated as a potential viable methodology to use for student project-based authentic stochastic learning. The curriculum was also discussed as a possible tool for teacher staff development training. Finally, implications of a statistics curriculum used with younger students and further research directions were suggested based on the literature review and implementation of *The Survey Toolkit* currriculum by the author's students.

Given the current trafficking of misinformation and fake news it is imperative more than ever to provide students' learning experiences and skills applying fundamental principles of statistics in development of authenic research projects. *The Survey Toolkit* and *TinkerPlots*® curriculum teaching research collecting skills and information gathering techniques in the context of learning statistics may serve as an appropriate entry program for elementary and middle school students.

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WEB 2.0 IN NIGERIAN UNIVERSITY LIBRARIES: A LITERATURE REVIEW

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ABSTRACT: In this article, the author reviewed literature on Web 2.0 in Nigerian university libraries. Web 2.0 is not just commendable, it is necessary and for to service patrons without it in this century is to be left behind in information provision. Library users presently are increasingly becoming technologically inclined. They expect local services to be virtually presented and want information at their beck and call for their individual fulfillment. Web 2.0 is a necessity for librarians because it offers feedback and comment opportunities that allow them to feel engaged with patrons and other colleagues professionally. It is an inexpensive and effective way of interacting with patrons that has never been possible before. Web 2.0 is much more than a mirage, it is real. It is a new and an innovative attitude, a total values system and offers new ways of doing library work. The various manifestations of web 2.0 such as Blogs, Instant Messaging (IM), Flickr, Wikis and Really Simple Syndication (RSS) and challenges to deployment in university libraries were discussed. Deploying Web 2.0 could be frightening but it is necessary that as information professionals, librarians should know the potentials of Web 2.0 if we are to be relevant and ably harness our users' astuteness.

Keywords: web 2.0, Nigeria, university library, manifestations of web 2.0

INTRODUCTION

At conferences, organizational offices, and in fact, in every opportunity in the library world and at the reference desk a dynamic model for library service is being discussed. If you and your library staff are not among those already discussing web 2.0, know that you have been left behind. Web 2.0 could give a new lease of life to the way we serve and interact with our esteemed patrons. It is a new revolution in the way libraries work together with their patrons. Variations in technological developments on the Web have had a major influence on these modifications (Huvila, Holmberg, Kronqvist-Berg, Nivakoski, & Widén, 2013). The developments have also placed new ways of doing things by librarians' using their competencies and skills.

More concisely, writes (Notess, 2006) of the Web 2.0 concept represents a new trend of Web skills used to create more interactive and simple Web sites using recent technologies. Web 2.0 model is an arrangement for separating some of the current Web from that of the preceding era. About two decades ago there were many Web 2.0 technologies, but the present crops of Web 2.0 sites combine those technologies in different ways. For example, most Web 2.0 sites are interactive, with the capacity to without difficulty edit and transport objects. According to a book titled Library 2.0: A Guide to Participatory Library Service by Casey and Savastinuk (2016), the notion of participatory librarianship implies that library users and faculty members are important factors in relation to what the library is, does, and offers. This information comes from real world practice. With Library 2.0, a greater number of libraries would be afloat in the face of the types of budget cuts they have experienced in the last decade. In early 2000, public libraries across the United States were not doing well as a result of not taking advantage of Web 2.0 technologies. This resulted in their calling on private companies to take over, or closing their doors altogether. When libraries fail to change with the times, and more importantly, fail to even ask their users what kind of library they want, there will be no one to engage policy makers when funds are redirected from library services. United States of America is not an Island in this regard. Libraries in Australia have started employing participatory librarianship to make policy makers create the library the people want. As a result, the mentioned libraries are busier than ever. Bringing the community together is what Library 2.0 is all about just like the Fayetteville Free Library, New York.

Due to technological advances, libraries have enabled the creation of new services that before were not possible. Some of these new services are downloadable media, virtual reference, and personalized OPAC interfaces. These technologies have given libraries the capacity to offer enhanced, customer-driven service opportunities. The main thrust of web 2.0 is patron-centered modification. It encourages constant and focused change by allowing patron involvement in the establishment of virtual and physical services they want, and regularly appraising services. Web 2.0 reaches out to new users and better serve current ones through enhanced patron-driven contributions. Web 2.0 by itself is a step toward better serving our users because it is through its implementation that we can reach Library 2.0. In the current library world, particularly in academic libraries, we are used to focusing our attention and services on those users we previously know. Casey and Savastinuk (2010) quoting Michael Stephens explains on ALA TechSource, "As librarians, we must remember all our users." Libraries have formed the habit of providing the same services and programmes to the same users and are at ease with our provisions and remain unchanged. Stephens believed when thinking about this new model for library service, that "Library 2.0 will be a meeting place, online or in the physical world, where library users' needs will be satisfied through information, entertainment, and the ability to create own information resources thereby contributing to the ocean of content out there."

In what is Web 2.0? O'Reilly (2005) discussed the harnessing of the collective intelligence of everyone who uses a product or service. In a virtual environment, this takes the form of user-crafted social networks, feedback and user evaluations. Sites such as Facebook, Amazon, Twitter, Flickr, and MySpace rely on high levels of user involvement to increase the value of the product and service (Imran, 2011). Other ways to involve patrons and introduce new content to them are through Blogs and wiki. Casey and Savastinuk (2010) asserted that in Philadelphia, Temple University Library employs blog to provide a place for "news update, events, and chatting." Ann Arbor District Library (AADL), MI, went a step further and turned its Web page into a blog (a chance to form user community and also quickly respond to feedback). In Saint Joseph County Public Library in South Bend, IN, the resourceful librarians used open source wiki software to create a successful subject guide that facilitates patron opinion and feedback.

Web 2.0 provides library clienteles participation in the services libraries offer and the manner they are used and they will be able to employ library services to their own needs and advantage. In fact, the use of Web 2.0 applications in libraries has increased. This is due to the fact that they are easy to use, intuitive, and enable the direct and speedy online publication as well as dissemination of user content (Schneckenberg, 2009). Basing their argument on Clausen (1999), Chua and Goh (2010) highlighted four activities of the library to include information acquisition, dissemination, organization and information sharing with relevant web 2.0 tools.

To increase your library's visibility, appeal and worth, consider implementing customizable web 2.0 services. Imran (2011) indicated that web 2.0 model put together our users' knowledge and uses it to enhance and advance library services. User remarks, tags, and evaluations feed user-created content back into these web sites and this creates a more informative product for successive users. In the course of creating customizable services you should also consider user privacy. Libraries and their librarians should be wary of protecting users' privacy with technology-based services as they are with traditional, physical library services. Some ways through which privacy could be preserved, includes allowing anonymous comments, remarks and tagging within the catalog. For example, library patrons should not be told to identify themselves publicly before they are allowed in online services.

Your library could already be amongst those offering some services that can be termed Library 2.0, if your library combines Library 2.0 options with an outline for constant modification and patrons' input included into other procedures within your library (Ata-ur-Rehman & Shafique, 2011). Due to the fact that every library has a different starting point, the essentials of the Library 2.0 model will be different for each library as system. You will be able know how library 2.0 model will work for your library through cooperation between community of users (Imran, 2011).

Web 2.0 and some of its Manifestations (Typology)

Bower (2015) and Imran (2011) made a brief explanation of few Web 2.0 applications below:

- Blog or Web Log is a major application of Web 2.0. Adomi (2011) described weblog as a certain type of website where the information is presented in a persistent sequence of dated entries (it is also called an online diary). It can be created by an author and supported by a community of authors. Blogs has the characteristics of having brief entries but presented in reverse order and chronological. In terms of update, the webpage can be updated anytime – hourly, daily, weekly or monthly as required (Kejewski, 2007) and some blogs permits visitors to add remarks/comments to the records (Morris & Allen, 2008). The blogs are types of publication (Maness, 2006) and the process of publication of the ideas on the web and to get the comments from other users of web is called blogging. Clyde (2004) observed that blogs though dating back late 1990s is a one-click process of publishing posts and is a recent Internet occurrence. Some libraries the world over are using blogs for ease of information dissemination to defined patrons. According to Clyde (2004) blogs are the fastest emergent means of information dissemination when compared with the World Wide Web. Blogs can be formed as a single-person work but some are created and published as joint effort.

- Instant messaging is a form of text-based actual communication on the Internet that has already been accepted with enthusiasm by the library community. Instant messaging permits users to retain a list of individuals that they intend to network with. Mannes (2006) noted that Instant Messaging (IM) allows actual text communication amongst persons and that libraries have started using it to provide "chat reference" services, where patrons can talk with librarians just as in a face-to-face reference situation. Messages can be sent to any of the individuals in your list that is sometimes called a buddy list or contact list, in as much as that individual is connected. The moment a message is sent or in sending a message, it opens up a small window where you and your friend at the other end can type in messages that both of you can comprehend. IM involves the use of a client programme that connects with an IM service and differs from e-mail because conversations are in real time. A majority of services provides a “presence information feature”, showing whether persons on one's list of contacts are currently online and also available for discussion. IM is an indispensable device which may help librarians to provide library services. Maness (2006) claimed that IM was initially Web 1.0 application because it often requires the downloading of software but now, IM can be classified as Web 2.0 application because IM is accessible through browsers from most of service providers like MSN, Google Talk, etc. IM is very much in use for online reference services in libraries. ‘Ask a librarian service’ is provided by instant messengers all over the world. For example, a study of top 100 university libraries revealed that IM features have extensively been used in libraries to provide quick online reference services using IM technology (Harinarayana, 2010). IM, noted Currie (2010) can be utilized to offer virtual reference services by engaging staff at public desks during night shift and through weekends when the library is closed for other services.

- Wikis, like email has revolutionized cooperation within enterprise in terms of communications. Wikis allow several users to create, revise and connect multi-page websites using their web browser, and instructors and students use this to generate collaborative information sources and for project terminals (Bower, 2015). A Wiki is an additional example of collective creative effort. Numerous patrons the world over can build information sources via this application. An example of this kind of collaborative work is the Wikipedia. Through the wiki service, a library can permit social collaboration between librarians and patrons, by making the study group room virtual (Maness, 2006). Patrons in libraries can help generate files and organize tutorials with Wikis which are the combination of many other technologies like tagging, messaging and blogging (Maness, 2006). Wikis could be employed in information and document management, project management, planning, conferences, directories, and many more. Wikis are simple to use without exceptional preparation or adequate practical expertise. Bower (2015) reported in his study that 33% of institutions are already employing wikis and projected that another 32% are strategizing to do so without further delay.

- Another Web 2.0 technology which enables patrons to bring updates and feeds from other websites is called Really Simple Syndication (RSS) or Rich Site Summary. A very simple instrument that is used to get the newest stories, keep news groups informed and latest information in magazines and journals. According to Obasola and Mamudu (2015) RSS can be used for current awareness services where patrons receive signals on newly acquired resources and services provided by the library. It is an arrangement for providing repeatedly, changing network content. In many news websites and weblogs, online publishers provide their content as an RSS Feed to any person that has interest. It resolves issues for people who constantly use the web and permits you to without difficulty stay connected and up-to-date by retrieving the current content from the sites you desire. Advantages for using this too are that your time is saved by not visiting each website separately and your privacy is also ensured. RSS feeds abound in many types of web sites which may be of use to information specialists. For easy viewing in the workplace, professionals use newsreader to aggregate syndicated web content such as podcasts, news headlines and blogs in a single location. Some libraries that discovered effectiveness in blogs and wikis are recognizing that RSS is necessary in introducing their content to patrons. Feed from a site are created that readers can then add into an aggregator to create one access point for numerous sources (Davison-Turley, 2005). In a recent study of Australian University Libraries, Linh (2008) reported that RSS was found the most widely applied technology.

- Flickr is a virtual image distribution application. It is employed to share and distribute images in online communities. It is also a good source for sharing and distributing various events by means of images and image collections. The aforementioned lets users to upload, distribute and identify images by keywords. These labels or identifiers are very useful for recovering important images (Angus, Thelwall & Stuart, 2008). Often, Flickr is put behind Facebook and Twitter in terms of ranking. However, there is no healthier means to figure out a robust communal system without Flickr (LIS, 2016). In line with the above, Hooser (2013) noted that when social media professionals advance /promote a campaign, various persons may go to their habitual outlets - twitter and facebook with good reasons. This is because these social media network outlets easily spread to large and busy audience. Flickr is repeatedly ignored but it is an effective social media network where importance is placed on visuals such as photos and short video clips. Patrons can bring together their Flickr photos together into "albums" which are flexible than the customary folder-based process of forming files. Flickr photo album represents a type of clear-cut metadata rather than a physical order. Flickr albums could be arranged into "collections", which can themselves be additionally being structured into higher-order collections (https://en.wikipedia.org/wiki/Flickr, 2016).

Awareness of Web 2.0

The Chartered Institute of Library and Information Professionals in Scotland and Scottish Library and Library Council (n.d.) observed that the universal characteristic of web based services indicates that libraries can service a vast audience through serving patrons in the virtual arena than would be possible at a fix place. Instead of just waiting for users to visit us, the library can create online spaces in the social media websites where interaction can begin. This presents opportunities to appeal to user groups, such as teenagers who are less likely to visit the physical library building. Improved awareness of library services and contribution to a progressive image laundering, may lead to increased visits.

In a study by Atuloma (2010) 67.7% of the surveyed subjects were hearing about library 2.0 for the first time, while only 9(29%) were aware of the technology before the study. In short, a summary of the results indicated insufficient awareness and understanding of what constitutes web 2.0. The subjects were equated based on institutions. Analysis of variance for knowledge yielded (F=.257; P=.775), perceived support for library 2.0 (F=1.77; P= .188) and attitudes towards library 2.0 (F=.936; P=.404) In fact, there were no significant variations between institutions.

Xu, Ouyang and Chu (2009) surveyed 81 academic libraries in New York state and the study revealed that less than half (42%) of the libraries adopted one or more web 2.0 tools such as blogs and that the implementation of the tools varies in individual libraries. Instant messaging takes the lead in terms of frequency of use, followed by blogs and RSS. It can be inferred from the above that few libraries are aware of the use of web 2.0 tools.

Obasola and Mamudu (2015) in their study established that the implementation of web 2.0 technologies in information services delivery in Nigerian academic libraries is still at its infancy. This is because only a few of the libraries studied have a suitable structure for the implementation and combination of these tools for information services delivery. It was also found in the study that most of those in this category, that is, the libraries implementing web 2.0 tools are privately owned institution of higher education. This means that implementation of web 2.0 technologies on the websites of federal and state universities in Nigeria is not progressing like those of their counterpart in the private universities.

The various uses to which Web 2.0 tools could be employed are knowledge sharing and management, user services, communication, making yourself heard, knowledge gathering, campaigning/social reform, community building, experience tracking and as a newsletter (Siemens, 2002). However, lamented Adomi (2011) the use of blogs for library services is not yet popular in most Nigerian libraries. The reasons for this ugly situation Adomi continued, are inadequate awareness of the existence of the technologies and/ or how to use them even when they are freely available on the web, inadequate network technologies for service provision and technology skills among others. The excuses notwithstanding, the time has come to embrace the use of web 2.0 technologies, especially weblogs to enhance library services in Nigeria.

Challenges to deployment of Web 2.0 technologies

Atuloma (2010) citing Njoku (2008) indicated that the problems facing the information profession in Nigeria and Africa as a whole are linked to:

- Energy problem: incessant electricity stoppages restrict all computer linked activities such as the use of Blogs and other online tools.
- Inadequate communication infrastructure, and
- Inadequate funding: as a result, information and communication technology infrastructures are accessible only to limited privileged organizations in private sector, institution of higher education, research institutes and a few public institutions.

The above challenges could hamper the implementation of web 2.0 in Nigerian libraries. Also, Krubu, Okoh, Ebunuwele and Odion (2012) in their study of the extent of use of Information and Communication Technology

(ICT) by undergraduates in Edo State, Nigeria reported that institution of higher education experienced the challenge of poor infrastructure, as a result, unable to fully meet the information needs of students regarding full access to ICT technologies. They suggested that that internet services should be provided in all the faculties to aid student academic work.

Another major challenge is the creation of new librarians. This encompasses transforming the present crop of librarian from an information provider into a knowledge worker, that is, from somebody who only provides access to information to somebody who vigorously lends a helping hand to the user in obtaining the desired information. The transformation would be exhibited in a variety of ways and roles for librarians. Roles such as information literacy instructors, information creators and portal publishing supervisors, community information specialists and coordinators, advisors for children's culture, consumers' rights advocates, and subject experts in completely all fields (Adomi, 2015).

On the foreign scene, Arif and Mahmood (2010) in Pakistani noted that there was scarcity of literature on the usage of Web 2.0 applications. Only one study according to Arif and Mahmood (2010) has been conducted to date to explore the adoption of Web 2.0 technologies in Pakistani libraries. Their study has revealed that inadequate Internet skill was the main factor militating against the adoption of Web 2.0 technologies in the libraries. One hundred and sixteen, 116 of the respondents used Web 2.0 tools to deliver library services. Instant messaging and social networking are the major services to which web 2.0 technologies were used for in the study. Half of the respondents used electronic groups, blogs and Wikis. Three respondents used podcasting services, while Forty-five of the respondents used RSS. They also found that inadequate computer and computer literacy skill and inadequate Internet facility were the key limitations to implementing Web 2.0 technologies in the libraries.

CONCLUSION

Web 2.0 is the application of interactive, collaborative, and multi-media web based technologies to web-based library services and collection (Maness, 2006). Web 2.0 is about new and innovative ways of creating, working in partnership, editing and distributing user-generated content virtually. Web 2.0 can be realized only by adding innovative functions and structures directly into the content (Abram, 2005).

According to Casey and Savastinuk (2010) at present, libraries have a penchant to design, implement and fail to recall or forget. Web 2.0 technologies tries to modify this line of thought by developing a timetable that includes frequently soliciting patron response and appraising and updating services. New and current library services should be reexamined regularly to make sure that they are still meeting projected aims. Also, outdated library services should be appraised to determine if any feature requires modernizing.

You don't use what you don't know about. In libraries, applying web 2.0 is a question of awareness. Is your library prepared for this kind of change in technology? Without mincing words, the answer is no. Librarians in this part of the world seemed not thinking along this philosophy, but there is the need for us to change. Innovative change in the way information is generated and shared is the main aim of the Web 2.0 discussion, and this is the reason it is critical. Our contents are useless if our libraries are kept under lock and key on our own web sites and don't get it out there for patrons to use as they want to.

RECOMMENDATIONS

Deployment of web 2.0 tools would create a significant as well as extensive transformation in the advancement of academic libraries in Nigeria. Libraries in third world countries must therefore endeavor to adopt the technology. Although, lots of the talk about web 2.0 involves technology that is capital intensive, university libraries with inadequate technology funding can gradually work toward web 2.0 adoption and implementation. When technology choices are restricted, consider physical tasks that will better serve present patrons as well as anticipated ones. You can develop ideas for new, affordable offerings, as well as physical services from surveying both current and potential patrons, other libraries, and through staff feedback. Deploying Web 2.0 could be frightening but it is necessary that as information professionals, librarians should know the potentials of Web 2.0 if we are to be relevant and ably harness our users' astuteness.

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STRATEGIES FOSTERING DEVELOPMENT OF INNOVATIONS IN THE AREAS OF STEM

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ABSTRACT: Science and technology ensure the progress in all areas of human life. Prosperity of the country is strongly linked with a proper application of STEM (Science, Technology, Engineering and Mathematics) fields. To achieve this goal, highly educated specialists both men and women are needed. Children should be exposed to science and technology from early childhood and the national educational policy has to take into consideration all levels of education. Graduate students should possess necessary amount of knowledge to be able later on to introduce into their reality the innovations of science and technology. Recently, a new system called K-12 is introduced in schools. Since the science is a strategically important field, therefore a significant fraction of students should study science and engineering what within a time can be converted into innovation and economic growth of the country. Special attention should be put on female students and the existing barriers that may inhibit them from studying the STEM fields. In this paper, a short analysis of K-12 educational system is performed and some best practices encouraging young people to study the STEM fields are presented. The under-representation of women scientists and engineers on the top positions in academia are also mentioned. Additionally, activities of two global NGO organizations (INWES and INWES-ERI), partners of operational type with UNESCO, whose primary objectives are to advance education in STEM are introduced.

Keywords: K-12 system, innovations, STEM, women's career

INTRODUCTION

Science, engineering and technology penetrate almost all aspects of modern life and are the key to solving many of today's most up-to-date and future human challenges. Education of the young generations in the highly competitive 21st century should involve both Science and Humanities although it is the science; however, that ensures civilization development. In October 1996 International Conference of Women Engineers and Scientists (ICWES10- International Conferences of Women Scientists and Engineers) was held in Budapest [Szemik-Hojniak]. Among many excellent lectures presented by the world reknown women scientists and engineers especially, the one particularly interesting was given by the civil engineer-baroness Platt of Writle of the United Kingdom [Georgiou, Platt]. In her lecture, she presented the main ideas of Science and Technology Program entitled “Realizing our Potential” prepared by the British Government Office of Science”. It is worthwhile to quote few phrases from that report to underline how important is for the nation to educate young generation in a highly competitive 21-century: “The understanding and application of science are fundamental to the fortunes of modern nations. Science, technology, technology and engineering are intimately linked with progress across the whole range of human endeavour: educational, intellectual, medical, environmental, social, economic and cultural” [Georgiou].

Each Government should demonstrate initiatives of that kind and realize that prosperity and quality of life of the nation is strongly linked with a proper application of Science and Technology. Science and education, is a long-term process and, in a fact it has to begin from the early childhood provided by parents, neighbourhood, school and in general, by the society.

Education for Innovation

In today`s world, political, socio-economic, technological and environmental challenges, affect development of new attitudes in science, technology and IT methodologies. Observations show that the global competition for talents and resources already has begun and apart from well trained teachers also “Policy makers have a key role to play in helping to create the right conditions for the adoption of new technologies and knowledge” [Angel]. In the nearest future, new emerging markets will require new type of skills both from alumnees of highschools and university students.

Looking to the future and creating a new generation of scientists and engineers, we should take into account not only the worldwide issues of education in STEM but also identify key scientific ideas and practices in education of all talented individuals, i.e. men and women, minorities as well as persons with disabilities. To ensure rapid technological progress in the country, all of them have to be employed in various areas of the social life. National educational policy has to take into consideration all levels of education starting from the primary and secondary schools and finalize on the highschools and universities. Certain intellectual level of students of all types of highschools and universities has to be ensured. Graduate students should possess necessary amount of knowledge, and ability to apply this knowledge to surrounding world to be able later on to introduce into their reality the innovations of science and technology.

May be in this place, the notion of innovation should be defined. We all understand that innovation is linked to the launch of new ideas and generally, it is a joint process.
Using multidimentional UNESCO definition [UIS]:

- Innnovation is a new or substantially improved product (good or service),
- A new marketing method
- A new technological process
- A new organisational method in business practices, workplace organisation or external relations.

As far as the place of a given country in global innovation is concerned, the first one is for Israel, where 4.4 % od its GDP is invested into science. The map presented beneath shows the Global Research and Development expenditure [in %] worldwide.

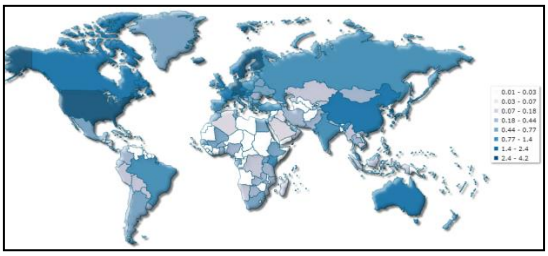

Figure 1. Global research and development expenditure into science (% of GDP) [UIS].

The corresponding values per country are gathered in Table1.

Table 1. Global research and development expenditure (% of GDP) invested into science [UIS].

Country	[%] of GDP	Country	[%] of GDP
Israel	4.4	France	2.23
Japan	3.47	China	2.01
Finland	3.31	UK	1.63
Sweden	3.30	Canada	1.62
Danmark	3.01	Italy	1.26
Germany	2.85	Russia	1.13
USA	2.81	**Turkey**	**0.92**
Australia	2.25	India	0.82
France	2.23	**Poland**	**0.80**

Innovations are strongly related to economic development and are the key factors to increase the profit, productivity, innovations and country`s GDP.

The young generation, i.e. graduates of high schools and universities need to be well prepared and creative to provide innovations later on. Thus, we have to know what all students should learn by the end of high school. It is interesting to note that nowadays, a new system, preparing youth for the universities, called K-12, raises popularity worldwide and is being already implemented in many countries. This specific teaching system is now a new educational mode that is somehow different from the conventional methods. It covers the education from kindergarten till the 12th grade and introduces a more significant common work between teacher and student than before. In K-12 system, the content and resources have changed to a significant degree and the teacher needs to arrange a lot of question-answer sessions and assignments that would lead to effective learning habits in students. Schools are now striving to invest as much as possible in their infrastructure to create the best learning conditions for their students. Students, utilize these facilities to provide for themselves the optimum learning. Exploring one of the advices of the National Academies Report in the USA [Consensus Study Report], one may say that country`s talent pool can vastly increase by developing and improving K-12 science and education.

Educational programms of this system have to capture students' interest and provide them with the necessary foundational knowledge in the field. Educational programme in these classes should involve the following [Pellegrino]:

1. 1.Cross-cutting approach combining research with their common use in science and engineering,
2. Practices and participation in scientific and engineering projects
3. Fundamental ideas of exact sciences, life sciences, earth and space sciences as well as for engineering, technology, and the applications of science.

This task, places great responsibility on higher education institutions, and especially on those that train the teachers. We must remember, that the main purpose of the K-12 system is to enable all high school graduates to gain sufficient knowledge of science and engineering so that they could later on engage in public discussions about science, understand scientific and technical information, and continue careers in accordance with their interests.

Special activities should also be undertaken by Governments, National Foundations and Non-Governmental Organizations (NGO) that might help to improving teacher preparation. Certainly, many teachers need to be more provided with research experiences and an increased use of high technologies. Hence, special Programs Awarding for Excellence identifying outstanding science teachers (who could serve as models for the rest of school staff and play the role of leaders in the field of science and education improvement) are advised to establish [Madsen]. Regarding the female students, it is believed that the more information could be provided about scientific and engineering career at school, the younger women would take up natural sciences and engineering for their future studies.

Academic Knowledge and Social Empowerment of Women Scientists and Engineers

Europe

The economic growth largely relies on innovation and knowledge in science and technology what makes of science a strategically important field [Corsi, Saperstein]. In changing reality, science will continue its key role in development although it needs to undergo a sort of transformation, too. The inter-disciplinary cooperation between different institutions will be necessary and joint projects and programs may show to be relevant, particularly in situations when one partner has enough number of highly qualified scientists but small number of multi-disciplinary laboratories/equipment. The top country scientific institutions need to carry out more application-oriented research and faculty evaluation process has to be based on such criteria like number of patents, effectiveness of commercialization, technology transfer and others.

Universities should create friendly atmosphere also for women pursuing their carrier in STEM fields. The under-representation of women in sustainable development by contributing to technological advancement, industrial and economic growth is of special concern. Their full participation may be achieved both through academic knowledge and social empowerment. To increase their representation, specific public policy and programmes need to be implemented and analysed from the point of view “of their content, justifications, and the environment in which they operate in a socio-economic context” [Mazur]. From the report of European Commission published in “SHE Figures 2015” [EC] and presented as the “Glass ceiling index (GCI)” in Figure 2, results that in many European countries there is an under-representation of highly educated women on the top academic positions. The GCI (0-1) is a relative index that compares proportion of women in academia (grades A, B, C) with the proportion of women in the top academic positions (grade A-full professor) in a given year. Walue of 1, indicates that there is no difference between the two sexes from the point of their chances to get promoted. When GCI<1-means that women are with grade A, in larger number than in academia generally and GCI>1 shows the “Glass Ceiling” and lower chances of women to be promoted. Thus, the higher the GCI values the stronger is “Glass Ceiling”.

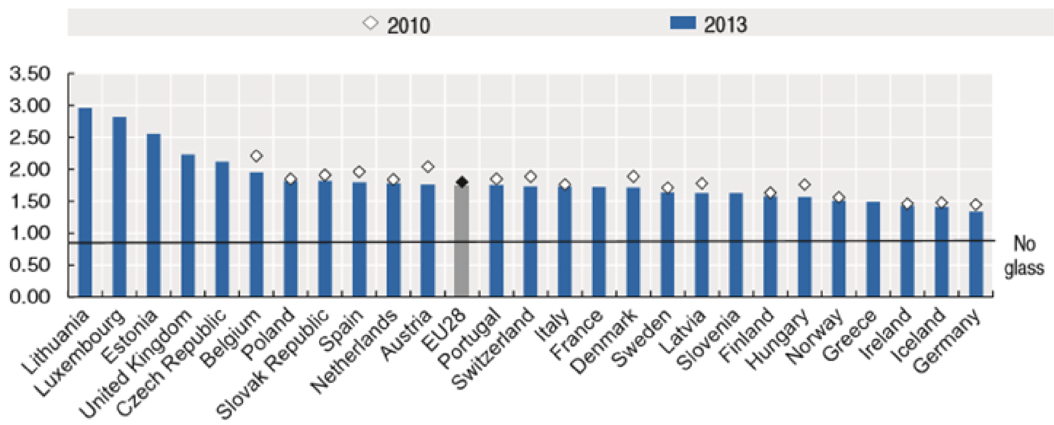

Figure 2. Women remain away from the top academic positions in Europe; “Glass ceiling” index (0.00-1.00) [OECD].

The European Commission working document on women and science reported that “Scientists have the longest period of qualifications, high level of career insecurity and international mobility as a key element of their careers” [Benchmarking Policy]. From these reasons, for women scientists to reconcile family responsibilities and work is very difficult.

In Europe, only 32% of researchers are women and women constitute 54% of teaching staff, but tend to be concentrated in the lower academic positions [MoRRI].

In the East Europe, women make up more than 50% of scientific population, thus they constitute a critical factor in development, especially because of their demographic strength.

Difficulties in advancements of women scientists, and academics means an inadmissible misuse of human resources. Although some of women have achieved academic knowledge, most of them do not hold decision-making positions. The reasons include: the lack of confidence, discrimination, and the lack of leadership training. One may conclude that highly skilled workforce of East Europe is not completely involved into economic growth.

Poland

General View

Accordingly to the Global Gender Gap Report 2015 [GGGR], Poland is characterized by the key indicators, as presented in Table 2.

Table 2. Key indicators of Poland [GGGR].

Total population (millions), 2015	38.00
GDP (US$ billions), 2015	429.52
GDP (PPP) per capita	23,952 USD
Population growth (%)	-0.12
Mean age of marriage for women	25
Overall population sex ratio(m/f)	0.94
Year women received right to vote	1918
Fertility rate (births per woman)	1.30

There are more women than men in Poland. Women constitute about 50% of the workforce. The population growth and the fertility rate are very low, indeed. Economic Participation and Opportunity of women and men in Poland [GGGR] are presented in Table 3.

Table 3. Economic Participation and Opportunity of Polish citizens [GGGR].

Type of data	F	M

Labour force participation	48%	61%
Income (PPP USD)	8,769	14,147
Legislators, senior officials, and managers	34%	66%

There is no illiteracy in Poland, and Polish women are in majority responsible for primary and secondary education. In general, they have a higher educational attainment than men.

As it is demonstrated in Table 4, the political empowerment in Poland looks more and more optimistically. In the last 20 years, Poland had three female prime ministers and generally an increasing percentage of women occupy with politics.

Table 4. Political Activity of Polish men and women [GGGR].

Political Activity	F	M
Parliament	27	73
Ministerial positions	22.5	77.5

It is important to note that in Poland, women have a full access to education. On their own decision it depends whether they choose it or not. Nevertheless, in spite of such possibilities, Polish women are still substantially underrepresented on the higher ranks of scientific and academic career [Reszke,]. About 20% of them work in technical sciences, 40 % in social sciences and 40% in medical and agricultural sciences [18]. Such statistical distribution is caused by a traditional rather than a liberal model of woman and her role as a " wife, mother or housewife" in Polish society. Due to stereotype ideas, professionally or publicly active woman, in many cases, does not receive a suitable encouragement neither from the men`s side nor from women in general. Since the collapse of the Communism in 1989, however, significant socio-economic changes took place in Poland and more rarely professions are divided into "feminine" or "masculine", as it used to be.

Statistics shows also that about 61 % of women scientists are married, 15% are divorced or in separation, 16% are single, and 8% are widows. They have one (33%) or two (30%) children, rarely three or more (5%) while 31% has no children at all [Iwaszczyszyn].

In conclusion, majority of Polish women scientists are married, have a small number of children and the most important for them is to have a happy family life and to keep equilibrium between profession and family obligations.

University of Wroclaw as a Case Study

One of a basic measures of high school development is the number of its students. In the 300 years history of the University of Wroclaw (founded in 1702) including 50 years of its post-was history, one may distinguish several periods of increase and decrease of the number of students. A dangerous permanent decrease of about 500 students per year took place around 1978 and lasted till 1985 [Zagożdżon]. It was an unprecedented phenomenon in the whole Poland. Those years in Poland, in the time of communist governance, were characteristic of a deep regress both in science and in high education. After, 1985, the number of students including the female students was slowly increasing every year.

The last statistical data on employement at the University of Wroclaw as demonstrated in Table 5, are the following:

Table 5. Employment at the University of Wroclaw (status quo on 31 December 2015 [BIP, Krzykawiak]).

Number of academic teachers:	3496
Full professors	261
Associate professors	307
Lecturers	542
Phd doctors	1017
Others (assistants, librarians, technical personel…etc)	1498

Total number of students:	32 000
Female students (%)	65
Residents	20 307
Evening & external students	11 250
Foreign students	806
PhD students	1334

An average number of female students at the University of Wroclaw is about 65 % and is slightly higher than statistical value (51.4%) for the whole Poland in years 2013-2014.

Women constitute also a large percentage of those completing the higher education. At the University of Wroclaw, the number of graduated female students in Mathematics, Physics and Chemistry is 78%, 29% and 69%, respectively. The least in Physics (29 %) indicates a significant underrepresentation of women in this „non-feminine" discipline. For comparison, in the Humanities, traditionally considered to be the female-dominated area [BIP], the number of diplomas given to them considerably exceeds those in natural sciences and reaches almost a 100 % [BIP]. At the University of Wroclaw, women constitute 15 % of full professors but in the Faculty of Chemistry this value, hopefully, approaches 30 %. Nevertheless, despite that women account for half of the university graduates they represent a minority at higher university positions. As prof. Etzkovitz, American sociologist, explains "They disappear in disproportionate numbers at each stage of the academic ladder"....a phenomenon often referred to as the "leaking pipeline" [Etzkowitz,].

A discussion whether being a wife and a mother excludes academic excellence and career progress is still opened in Poland especially that this situation is likely to almost all post-communist countries of East Europe. Accordingly to European Comission raport in 2013 [BP] among 25 countries involved in this report, only 5 of them (Romania, Turkey**,** Latvia, Portugal and Finland) have proportion of women full professors above 20%. This raport indicates also that in these countries also number of female PhD graduates are higher than in others. Hence, one may directly conclude that the more female PhD graduates is at the university, the higher percentage of females attain the title of full professor.

Networking and Non-Governmental Organizations

Nowadays, different social platforms including those of academic type (Research Gate, Academia, etc) enable the networking of scientists worldwide. In academic world, it is not enough to be smart and work the full day long, to make it to the higher rank of professional ladder. Important are connections and networking between collegues from different fields and specializations since it rises up the chances attaining the top position at academia or university.

INWES - International Network of Women Engineers and Scientists (www.inwes.org)

In today's world, rapid technological change and international competitiveness require the full participation of educated women in the country's development. This issue was analyzed during, the World Conference on Science for the 21st Century in Budapest 1990, convened by the UNESCO and the International Council for Science. During this meeting, the "*Article 90*" was adopted encouraging special efforts to be made toward the establishment of an international network of women scientists and engineers. It has happened that through the support and encouragement of the Canadian Commission for UNESCO, and a successful grant from UNESCO, 20 women representing 10 countries and 8 organizations met in Canada, in May 2001, to explore the creation of such a network. During the ICWES12 (International Conference of Women Engineers and Scientists) in Ottawa, July 2002, delegates from all over the world supported the creation of the INWES, i.e. International Network of Women Engineers and Scientists. The vote from representatives of 30 countries was unanimous. The author was in the first Interim Board and in two consecutive terms (2002-2011) served as the INWES Board Director, representative of East Europe Region.

In April 2003, INWES was incorporated as a non-profit corporation under the laws of Canada. INWES is a global network of organizations for women in Science, Technology, Engineering and Mathematics (STEM), reaching nowadays over 60 countries worldwide and about 300 000 members. INWES is a not-for-profit corporation, governed by a Board of Directors, representing organizations, corporations, universities/ institutes, and individual members in 12 global regions. The main INWES mission is to strengthen the capacity of individuals, organizations, and corporations; to influence policies in STEM worldwide and encourage the education, recruitment, retention, support, and advancement of professional women and students through an international network of organizations and experts.

In April 2008, INWES became an official NGO partner of the operational type with UNESCO while in April 2017 has received the consultative status with the Economic and Social Council (ECOSOC). INWES is the only one NGO organization on women in science and engineering with this ECOSOC status. It gives many possibilities for the INWES members to have a contact with the United Nations Secretariat and to be engaged in the various UN programs, funds and agencies.

As for now, this partnership involved a dynamic cooperation through helping women and girls worldwide to have access to education, especially in Science and Engineering. So far, apart from its annual activities (educational programs, regional workshop and symposia…) INWES organized several global conferences, so called ICWES (International Conferences on Women in Engineering and Science) conferences:

In 2002-Ottawa (Canada), 2005-Seul (South Korea), 2008-Lille (France), 2011-Adelaide (Australia), 2014-Los Angeles (USA) and in October 2017 the next conference will take place in New Delhi (India).
The Board Directors are leaders of different INWES Committees like:

- Project Committee - to identify opportunities to collaborate with organizations and corporations in providing programs, projects, and different events;
- Communication Committee - to share good practices among members by providing resources for professional development, and distribution of materials; to ensure appropriate representation of women on international and regional decision making fora,
- Advocacy Committee - to establish a worldwide web portal for information on women in STEM (www.inwes.org)
- Conferences Committee -to organize global ICWES conferences and Regional meetings, to collaborate with UNESCO and others on international campaigns to raise awareness about STEM issues and others.

The INWES branches were created already in Asia, Africa, Europe and in the USA it is under preparation.

INWES Regional Symposium on Women Scientists and Engineers of New EU Countries and Eastern Europe; "Strategies for a Highly Skilled Global Workforce"- June 2007, Wroclaw, Poland

The above mentioned reasons and the membership of Poland in European Union (since 2004), obliged the author, a women researcher, at that time in service as the INWES Board Director for East Europe Region, to organize in Poland Symposium on Women Scientists and Engineers. This, with the help of Ministry of Science and High Education of Polish Republic, University of Wroclaw, City Mayor of Wroclaw and CIDA (Canadian International Development Agency), was held at the University of Wroclaw in June, 2007. The Symposium objectives has been chosen to respond to the abovementioned problems as well as to establish the strategy that could increase the number of young people studying science and engineering and to retein women in careers in STEM fields. Discussion on the issue of balancing career and family responsibilities was also carried out and women saw a variety of models on how to balance family and career.

Polish universities decision makers and administrators such as rectors, vice-rectors and deans were also involved in panel discussion on how to promote natural sciences amongst highschool boys and girls. More than 70 women scientists and engineers from 22 countries participated in this Symposium. Those were women of East Europe and Russia, some of West Europe, USA, as well as those of Canada, Asia and Africa.

The post symposium recommendations included the following:

1. Identify factors that facilitate or inhibit :
   a) progression into IT or STEM PhD programs.
   b) completion of STEM PhDs.
   c) career advancement and retention in STEM.
2. Start-up with cooperative efforts with worldwide known STEM Organizations, including American Association for the Advancement of Science (AAAS), UNESCO, ***World*** Federation of ***Engineering Organizations*** (WFEO), International Network of Women Engineers and Scientists (INWES), Society of Women Engineers (SWE) and others.
3. Organize profiled highschools in direction of Mathematics, Physics and Chemistry.

4. Send enthusiastic and interesting men and women scientists/ engineers as the role models to several highschools to encourage teenagers to study natural sciences or engineering.

In a fact, representatives of scientists and engineers should be attached to secondary schools to work with teachers and simultaneously to eliminate the myth that to be a scientist or an engineer is either too difficult or for female students it is unfeminine. The last, is a very real fear in the minds of teenage girls. Regarding importance of the role models for teenagers, T*he Catalyst* [T*he Catalyst*] published analysis where the surveyed women identified "lack of senior or visibly successful female/male role models" in 64% and "lack of mentoring in 61%, as among the most important barriers to the advancement of women in academia and industry. A good example may be, the civil female engineers from the university of Technology in Warsaw who presently keeps the position of the Chief of Polish Petroleum "ORLEN" Corporation said that "she was fascinated by the work of her father, a civil engineer", which prompted her to study engineering. She later completed a master of science with distinction in structural steel design and PhD at the Technical University in Warsaw [Żochowska].

INWES-Education and Research Institute (INWES-ERI, www.inwes-eri.org)

INWES is a not-for-profit organization and therefore from time to time may experience some financial problems. and thereforhence, it has been decided to establish a separate, sister organization to better achieve its objectives with regard to funding education in STEM. INWES-ERI was established in 2006 and in 2007 was incorporated by letters patent under the Canada Corporations Act. In 2008- the Institute was designated as a Charitable Organization in Canada (BN# 82690 2751 RR0001) while in 2011, was also registred as a not-for-profit 501c3 organization through reciprocity by the United States of America. The Institute is governed by a Board of Directors, and activities are planned and administered through four committees: Program, Nomination, Finance and Communication.

INWE-ERI goals are the following:

1. awarding scholarships, bursaries and grants for students (boys and girls) wishing to study in one of STEM fields,
2. carrying out research in both developed and developing countries concerning the fields of STEM - publish the results.
3. acting as a resource centre and database for information concerning education in STEM fields and collecting best practices in encouraging students to study them.
4. developing and maintaining a website to raise public awareness concerning these fields of study and to make the results of research available to the interested public.

INWES-ERI-recent activities involve, workshops, debates, quizzes, and essay competitions (Canada, Africa), developing numerous recommendations to facilitate young generation, and particularly for females, to study STEM fields and to make women more visible at all levels.

Other Forms of Bringing Children and Young People Closer to Learning

Long Term Cooperation Between Universities and Highschools to Raise the Profile of Science in the School.

University of Wroclaw has such a 30-years lasting cooperation with one of the best Wroclaw highschools -"XIV LO Wroclaw" what for different universities of the Wroclaw Academic Center gives the best students. Learning exact science (e.g. chemistry, physics, informatics…) in well-equipped university laboratories and having a direct contact with academic staff, brings very positive educational results both for schools, and universities.

Apart from teaching highschool students at universities, there is a good practice of sending enthusiastic and interesting man and women scientists/ engineers to several highschools to encourage teenagers to study natural sciences or engineering and to serve as the role models, particularly for female students.

Organizing Mass Science Events for Children and Youth

A good example may be the case of the Wroclaw Academic Center where since 1998 till nowadays, both in Wrocław and in the surrounding towns, a mass scientific event called Festival of Science every year takes place. It involves enthusiasts of science from all university faculties, university researches (professors, doctors, phd students…), student scientific associations, Wroclaw and regional authorities and the school teachers. It takes 8 days in the city of Wroclaw and then extra two-days presentations in 4 towns of the region of Lower Silesia

(Wroclaw is its capital). School pupils and average tax payers participate in this event and find the answers on the cuttingedge civilization dilemmas of the contemporary world. The Festival of Science offers proposals in the form of lectures, experimental demonstrations, discussions, galleries, expositions…etc, from all scientific and engineering disciplines including such *avant gard* fields like Bio-, and Nano-technology. Humanities, legal sciences, socio-political, medical, economic, and art disciplines are also presented to a significant extent. Young people and especially school pupils have a chance to meet with science and engineering to decide later on whether to choose them for their studies or not.

Children`s Universities (UD)

In Poland, since 2007, the so-called Children`s Universities in several Academic Centers like Warsaw, Cracow, Wroclaw and Olsztyn have been established. Classes are conducted by scientists, specialists in various fields, artists and entrepreneurs and children have chance to participate in lectures and workshops trying to discover and understand the world around them. Already 20,000 children aged 6-13 years have taken part in such studies, learning many areas of science in an active and researching way. The content-related program is checked out by the Scientific Council, which together with Organizational Committee of a given UD elaborates the university program and invites the corresponding lecturers. Each year, around 500 researchers and specialists carry out more than 500 lectures and 600 workshops for children coming to colleges and universities.

Science Centers

In Poland there are four Science Centers and the most reknown is the first one, i.e. the Copernicus Science Center in Warsaw. Their goal is to promote and popularize science. These are not musea. There are no showcases or guides. Visitors can learn about the laws of nature by conducting their own experiments in interactive exhibitions. It's a space that inspires visitors to observe, experience, pose questions, and seek the right answers. It depends on how much one wants to take from this. In Copernicus Science Center in Warsaw, there are over 400 exhibits. Although at first glance we can get the impression of chaos, the exhibits are grouped thematically. The boundaries between them are fluid, as in the world around us. The most interesting things happen at the junction of science, interpenetrate and complement each other. Exhibitions in the Scientific Centers are like a living organism that is constantly changing. These places are very popular amongst pupils and high school students and tickets must be purchased well in advance.

CONCLUSIONS

The advancement of today`s cutting edge technologies along with the present and future international competitiveness, requires to ensure an appropriate education of young generation, specifically in exact sciences such as Mathematics, Physics, Chemistry and engineering. Children –boys and girls-should meet with science and technology as early as possible so they can further stimulate their ability to continue learning and research in STEM. The educational process of young people must develop intellectual potential, in particular creativity that should be directed to future innovations, invention and decision-making. The continued increase of scientific and technical knowledge should be ensured not only at grammar schools and highschools but also by the contacts and career orientation with universities, technical schools and high-tech industries. An additional help in popularization of science among the youngest generation are the Children`s Universities and Scientific Centers.

Public media also can help by inviting both female and male scientists/engineers into the STEM programs. They may play a role models for the young people, directing them to the right career path. Particularly, women scientists should get prominent positions in the programs related to science and technology, so they can represent the points of view of women, and serve as role models.

Beyond the abovementioned efforts fostering development of education and science, a great importance to increase the innovations has the innovative society. In such societies important are also certain psychological factors such as:

1. The social trust - the basic factor of innovative society- that is directly related to:
   - willingness to use new technologies
   - spontaneity and social openness
   - higher level of mobilization and activity

2.The social capital - factor of development of quality of life and civilization competences
3.The role of leadership in creating conditions for the development of innovation.
All these factors will provide strength, prestige and prosperity for the country.

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Section 3: Science Education

DELINEATING THE ROLES OF SCIENTIFIC INQUIRY AND ARGUMENTATION IN CONCEPTUAL CHANGE PROCESS

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ABSTRACT: The purpose of this paper is to address the relevance and discuss the importance of scientific inquiry and argumentation processes, which are indispensable elements of constructivist science education paradigm, in teaching for conceptual change. Inquiry based learning, argumentation and conceptual change theory are separately emphasized by educational researchers as useful tools to reach the ultimate purpose of science education, scientific literacy. These three concepts are strongly related, however the nature of their relationship is not explicitly discussed in the literature and therefore relationship is not apparently clear. This review offers a viewpoint on the links of these three major ideas and provides guidelines for those who plan or design learning environments especially teachers. This paper is divided into four subsections. The first part focuses on what conceptual theory means and second part provides a brief literature review on inquiry based learning environments. While third section concentrates on the relationships between inquiry-based learning and conceptual change theory, the last section explains the position of argumentation among these educational concepts.

Keywords: conceptual change theory, inquiry based learning, argumentation

INTRODUCTION

With each passing day, the effort of humankind to understand and learn about the natural world continues to grow. We are regularly bombarded with scientific and technological developments in printed and electronic media. Advances in science and technological applications provided us with powerful and immediate benefits and improved our health, materials, and life in a short period of time. However, the same technologies and scientific advances are also blamed for, with their unexpected deleterious consequences, enormous global problems such as pollution, extinction of species, overpopulation, global warming, deforestation, and desertification. Consequently, it can be argued that although the benefits of the new scientific and technological developments are immediate; their cost is high when we consider the long-term environmental and social consequences which are usually hidden and unpredictable. Maybe we are not aware of the importance of understanding these developments and problems which so powerfully affect our lives. These are not only the concerns of the community of scientists but also all individuals, who are the "active" part of the society, directly or indirectly make decisions about these issues and affect our shared world. However, science seems to be outside the average individual's ability to comprehend and evaluate because it is often associated with technical jargon which is not comprehensible to the lay public. In order to address these concerns, the National Research Council (NRC,1996), uses the term "scientific literacy" as the ability of individuals who use scientific principles and processes to make decisions and to get involved in discussions about issues which affect the public. Science, technology, and values/morals of society are three different but interrelated constructs. As a result of their dynamic and operational nature both science and technology constantly influence the society not only by creating new values (Cowan, 1998; Martin, 1998) but also influencing how we construct our identities (Mesthene, 1997; Winner, 1997). The interplay of science, technology, and society can be conceptualized as multiple ways of interaction (Brickhouse, 1998).

Scientific literacy is defined as "knowledge and skills in science, technology, and mathematics, along with scientific habits of mind and an understanding of the nature of science and its impact on individuals and its role in society" (AAAS, 2001, p. vi). When the dynamic and operational nature of science and technology are considered, the need for individuals' critical thinking skills is apparently clear. Since there is no one (single) understanding of the nature of science (Alters, 1997a, 1997b; Matthews, 1996), it is important to promote and encourage students to develop multiple understanding of nature of science. Successful critical thinking about the interrelationships among science, technology, society, and environment is only possible when individuals achieve to develop multiple understandings of the nature of science.

Recently, generating scientifically literate citizens has become an exceptional goal for countries; this goal turns out to be a main ambition for most educational policies. The launch of Sputnik by Soviet Union in 1957 is the most effective event which pushed countries to take the decision to change their educational policies and their curriculum (Aikenhead, 2003; Puvirajah, 2007). The reform movements in science education specifically aim to generate students who possess higher order thinking skills and needed cognitive strategies such as selecting, organizing, and utilizing scientific knowledge for a productive life (Hurd, 1998). Individuals who have higher order thinking skills and use cognitive strategies not only be able to monitor developments in science and technology but also play essential roles in making decisions on social and political issues.

Educational reform must aim to prepare scientifically literate citizens in this century and researchers must make an effort to integrate inquiry based teaching and scientific argumentation to their curricula to accomplish conceptual change if it is necessary. Consistent with this line of thinking, the next section describes fundamentals of inquiry based learning, scientific argumentation, and relationship of these two concepts to acquire desired conceptual change.

What are the relationships among, conceptual change theory, inquiry-based learning, and argumentation?

Assessing alternative explanations, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims are all seen as essential components in constructing scientific arguments (Latour & Woolgar, 1986). Furthermore, argument is central in the process of conceptual change as described by Posner, Strike, Hewson and Gertzog (1982). Argumentation provides opportunities for learners to negotiate their understandings, and consider and evaluate each other’s arguments. Conceptual change depends on socially constructing and reconstructing one’s own personal knowledge through a process of dialogic argument (Driver, Newton & Osborne, 2000).

In this section, a theoretical approach is provided for delineating relationships among, conceptual change theory, inquiry-based learning, and argumentation. These three concepts are strongly related, however the nature of their relationship is not explicitly discussed in the literature and therefore relationship is not apparently clear. In this chapter, we first present the process of scientific knowledge generation by the community of scientists and how this process is integrated in school science classrooms over time. Subsequently, we explain how this process fits to conceptual change theory. Before presenting “how do scientists produce scientific knowledge” and “how do educational scientists integrate the idea of –students as scientists- to school science classrooms”, we need to explain briefly what conceptual change theory is. Thus, we would be able to show links between aspects of inquiry-based learning what will be discussed later and conceptual change theory.

Conceptual Change Theory

Basically, conceptual change theory is focused on how individuals reconstruct their cognitive schemes and models for change of conceptions ‘under the impact of new ideas and new evidence’ (Posner et al., 1982, p. 212). Posner and his colleagues state that individuals’ cognitive frameworks (they used the term conceptual ecology) can be modified (assimilation) or can be entirely changed (accommodation) according to new concepts’ conformity to their existing conceptual ecology. Apparently, generation of this theory took its roots from the work of Thomas Kuhn (1970). According to Kuhn all individuals have general obedience to the scientific community which they belong. He called these general acceptances “paradigms”. Thus, all scientists generate research questions, design research, construct new explanations and test their explanations under the light of the paradigm to which they belong. These commitments to the paradigm continue till there are contradictions which occur between new explanation and the theoretical basis of the paradigm. Hereby, there are two situations in behalf of scientific progress (Kuhn, 1970). The first one is, if new explanation works compatible with the core ideas of existing paradigm then there is no need to make any paradigmatic changes which Kuhn called this condition normal science. As an analogy, this situation is matching up with the assimilation concept in conceptual change theory suggested by Posner and his colleagues. They argued that sometimes students use their existing conceptual frames to deal with new phenomena. If students’ existing beliefs, knowledge, and experiences are well-suited with new concepts, then new concepts are easily linked to the frames that became ready to new learning situations. The second situation for scientific advancement in Kuhnian thought is scientific revolution which is new phenomenon that dealt by scientists does not match with the core ideas of the paradigm. Under this situation scientists might make radical changes about their beliefs, knowledge and experiences as a result the paradigm they belong changes. Kuhn argued that these kinds of changes are extremely difficult. Accomplishing such changes means reorganizing all conceptual and cognitive frames changing whole worldview similar to converting to a new religion. This Kuhnian thought matches with the term accommodation in conceptual change theory. Posner et al. (1982) defined accommodation as extreme changes in the case of discrepancies in the new phenomenon and the conceptual ecology of the individuals. Similar to paradigm shift, the kind of deep changes required for accommodation are extremely hard and they need some conditions to succeed. Posner et al. (1982) has indicated that there are four important conditions for accommodation to occur:

- Dissatisfaction with an existing conception; if students' existing ideas do not work for solving a problem or generating an explanation about a natural phenomenon anymore, students feel the need to change their current ideas.
- Intelligibility of a new conception; if a new conception is not intelligible, students cannot adapt to a new concept in their cognitive scheme.
- Initial plausibility of a new conception; a new conception must look initially consistent to a learner.
- Possibility of a fruitful research program; a new conception has to have the power to solve new problems which satisfy a learner more than the previous conception for future research.

Scientific Inquiry and Inquiry-based Classrooms

The analogical approach about scientific inquiry and inquiry-based classrooms allow us to understand how similar the scientists and students are in case of generating "knowledge" (Pera, 1994; Magnusson, Palincsar & Templin, 2006). Two kinds of scientific inquiry model, introduced by Pera (1994) and Magnusson et, al. (2006), are 'The Methodological Model and The Dialectical Model.'

Scientific inquiry, in a traditional perspective which Pera (1994) called The Methodological Model, "is a game with two players: the inquiring scientist who asks questions and nature who provides answers" (Magnusson et al., 2006, p.132). Implementation of this approach to the educational programs was known as the discovery learning approach in 1960s' (Magnusson et al., 2006). In a discovery learning approach, students are exposed to particular questions and experiences in such a way that they "discover" the planned concepts for themselves (Hammer, 1997). In later years, question marks began to increase for discovery learning as a result of the studies related to the nature of science (Magnusson et al., 2006). In accordance with these changes about perspectives on nature of knowledge, traditional inquiry has given its place to contemporary scientific inquiry which Pera (1994) called The Dialectical Model. Instead of traditional inquiry, contemporary inquiry includes three components such as; a scientist or a group of scientists that we call benchmark, nature itself, and another group of scientists that debate with the first group according to the features of scientific dialectics (Magnusson et al., 2006). When we compare these two aspects of inquiry, we can see that the most distinguishing thing is that the contemporary inquiry aspect contains another group of scientists who examine the reliability of findings of the benchmark group. This difference makes contemporary inquiry more consistent than traditional inquiry because there is a community's agreement upon nature's correct answer. As opposed to a traditional aspect of inquiry, contemporary aspect of inquiry focuses on scientists' use of their reasoning and thinking skills more. With this focus scientific inquiry reflects a distinct shift from science as exploration and experiment to science as argument and explanation (NRC, 2000; Zembal-Saul, 2009).

DeBoer (2006) argued that as scientists seek to understand the natural world through their investigations, students in inquiry classrooms try to move forward with their understanding of the principles and methods of science through investigations of their own. Therefore, educational scientists started to think that integrating the idea of "students as scientists" to teaching programs would be more useful for generating scientifically literate societies in the future (DeBoer, 2006; Puvirajah, 2007). Based on this idea, inquiry-based teaching is seen to mean a classroom environment where students think and do research like scientists and also present their findings to their peers and get agreements on them (NRC, 2000, Harlen, 2004). Although it has started to scrutinized more recently, the message of this idea was offered by John Dewey approximately a century ago in 1909. Dewey stated that, doing science is more than gaining "knowledge"; there is also a process which has to be learned by students (NRC, 2000; Simon, Erduran & Osborne, 2006).

Basically, the inquiry-based teaching is defined as a teaching strategy where students describe objects and events, generate their own questions, gather data, analyze and interpret those data, construct explanations, criticize those explanations against current scientific "knowledge", and discuss their explanations with the other members of the classroom (NRC, 1996; Byers & Fitzgerald, 2002). It is clear that in order to achieve this process, students need some cognitive abilities and skills. NRC (1996) indicated that these abilities and skills are needed to be able to; (1) ask epistemologically and ontologically proper questions, (2) design and implement accurate research, (3) decide convenient research instruments, (4) think critically and logically about data and explanations, (5) generate alternative explanations and generate arguments to criticize them.

Features of inquiry-based classrooms

According to Goh (2002), student cohesiveness, self-esteem and confidence, a sense of belonging and motivation to learn are psychosocial dimensions which influence the learning environment positively. Thus, the promotion of the positive effects of these psychosocial dimensions depends on well-organized classrooms where supportive relationships with teachers and classmates are formed and an emphasis on participation occurs (Moss, 1991). According to Furtak (2006), inquiry-based classrooms have four dimensions which are; methodological, conceptual, epistemological, and social (Figure 1). *Methodological dimension* of the classroom has to do with the imitating the scientific inquiry process by involving students in a process where they generate questions and hypothesis, and analyze data and then interpret them (Cakir, 2004). It is unquestionable that providing a proper environment to students to develop such methodological skills is an essential part of inquiry-based classrooms (Furtak, 2006). However, without these skills students might be able to generate some ideas about an authentic question but they cannot plan a process which they want to criticize their own hypotheses and theories.

The *conceptual dimension* is about the content knowledge of students. Basically, when students try to produce an explanation on behalf of a natural event, they need to have sufficient content or theoretical knowledge about that event (Posner et al., 1982).

The *Epistemological dimension* of inquiry is especially significant as it relates to general purposes of science education (Hogan & Maglienti, 2001). The epistemic beliefs of scientists and students play a central role in the whole inquiry process (Lederman & Stefanich, 2006). Beliefs in regard to "What is science?", "How does science work?", "What is the nature of scientific knowledge?", "What is the impact of the social and historical milieu on scientific ideas?", "Who are these people we called scientists?" and "What is the role of empirical evidence in science?" are some of the aspects which have been frequently focused on by educational scientists. Puvirajah (2007) has argued that, engaging students in an inquiry process provide them to construct and/or to reflect on their beliefs about science. As very few students consider science as a process which examines the models and theories instead of science as a heap of certain and constant "knowledge" (Sandoval, 2003).

The *Social dimension* of inquiry process provides students with an effective learning environment. Constructing knowledge in a social environment is the main idea in contemporary inquiry-based classrooms. In such environment, students interact with each other and with their teachers to criticize their own ideas as they find opportunities to see alternative explanations to reconstruct their ideas. In this respect, Duschl (2007) has stated that during the inquiry process, discussions concerning the phenomenon which are investigated in the classroom require students to revise their concepts and beliefs about those phenomena. On the other hand, an effective science education program must develop students' abilities of discursive practices that enable them to apply their understandings of science to personal decision-making and engage them in public discourse about issues related to science and society (Driver et al., 2000).

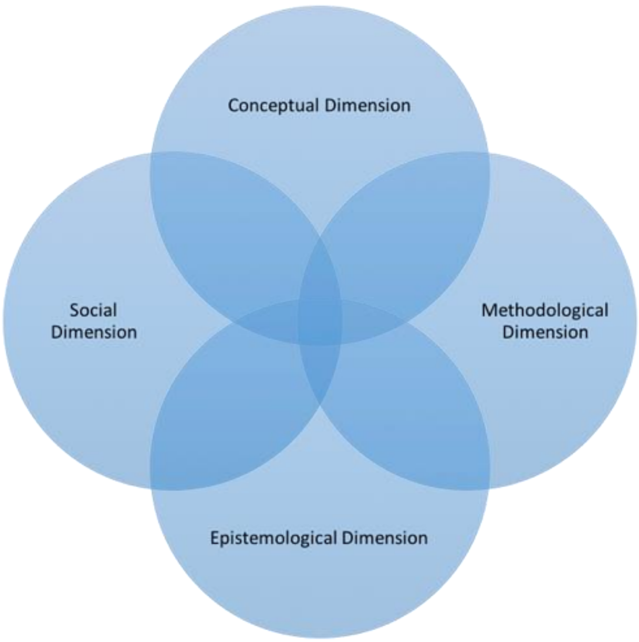

Figure 1. Dimensions of Inquiry-based classrooms.

These four dimensions about inquiry-based learning are working together to maximize students' meaningful learning. "Meaningful learning" is the integration of new concepts into our cognitive structures according to quality and quantity of our existing cognitive structures to new concepts (Novak, 2002). Clearly, if previous incorrect concepts have been memorized, changing such concepts is not big deal for students. Since memorized concepts have no links to cognitive structures and they are easily replaced. Unless, the previous learning occurs with the link of misconception then conceptual change is too hard for the learner. Inquiry-based teaching strategies help students to reflect on the reliability of their cognitive structures and the fitness of the new concepts.

Connecting inquiry-based teaching with conceptual change theory

All emphasized aspects of inquiry relate to the theory of conceptual change. Methodological and conceptual dimensions of inquiry are basically "back stage" of the process of conceptual change. These dimensions are concerned with all the preparation and also with the direction of the process. Conceptual and methodological aspects of inquiry aim to introduce individuals to new concepts and/or to skills for learning new concepts. We can see these two dimensions as "accessory aspects" for the theory of conceptual change. But the other two dimensions of inquiry have unique places for supporting the theory.

Epistemological dimension plays an essential role in conceptual change process. During the inquiry process, students construct new knowledge against their prior knowledge and beliefs (Posner et al., 1982). Therefore, if student beliefs about the nature of knowledge are shaped by contemporary views of nature of knowledge, then they can be open-minded about the uncertainty of existing concepts. Students with such beliefs can change their existing conceptions easier than biased ones. This does not mean that conceptual change process is too easy for that individuals; but we mean that whenever the student encounters a new phenomenon, students with such an attitude can ask the proper questions about new phenomenon and can decide what count as an appropriate answer for the new phenomenon.

On the other hand, we believe that the most important dimension of inquiry for changing inappropriate conceptions is the social aspect. We are aware that all aspects of inquiry must work harmonically for changing process. However, without a social dimension, this process might be a black box in which vicious cycles of individuals' judgments exist. As we recall, the first step of conceptual change theory is the need for dissatisfaction of individuals with an existing conception. Without the social aspect of inquiry, students (and also scientists) can generate alternative explanations but these explanations also take their roots from students' own experiences and beliefs. Therefore, students need an environment which allows them to see and weigh the alternative explanations that come from other individuals with plenty of different prior experiences. Hereby, the proper environment can provide great chance for dissatisfaction for students who have misconceptions and the need to change their conceptions. Precisely, classroom discussions of ideas are most powerful tools for criticizing and comparing alternative explanations. Meanwhile, students can find chances to cognitively challenge different ideas. However, unconstructed, improperly constructed, or question and answer "discussions" in the classroom can affect students negatively which might cause confusion. Thus recently, the social dimension of inquiry has received more attention and interest from the researchers (e.g. Driver et al., 2000; Duschl, 2000; Simon et al., 2006; Sampson & Clark, 2008). Instead of classroom discussion, these purposefully constructed and logical processes of inquiry are labeled as "argumentation". According to McNeill and Pimentel (2010), most of the teachers use traditional types of discussion structure, which is characterized with the initiation, response, and evaluation (IRE), in their classrooms. When a discussion is structured traditionally, teacher initiates process with a question (initiate-I), students respond to that question (respond-R) and finally teacher evaluates the student responds (evaluate-E). Such a triple construct results minimal student-student and student-teacher interactions. Traditional discussions have inappropriate structures for classrooms where contemporary inquiry-based strategies are used (McNeill & Pimentel, 2010).

What is this popular concept called "Argumentation"?

As the National Research Council (1996, p. 36) has stated, "an important stage of inquiry and of student science learning is the oral and written discourse that focuses the attention of students on how they know what they know and how their knowledge connects to larger ideas, other domains, and the world beyond the classroom". Therefore, the importance of argumentation shows itself by students' logical and critical reflections concerning their explanations and conceptions. In other words, argumentation is a knowledge construction process in which concrete representation of the ideas occur for peer review and revision (e.g. Driver et al., 2000; Duschl, 2000; Sampson & Clark, 2008). As a result, the definition of argumentation is "the process of argument construction that is used for support or denying explanations which are generated from the inquiry process" (Sampson & Clark, 2008).

Informal reasoning performed in non-deductive situations that are essentially the everyday situations of life and work (Voss, Perkins & Segal, 1991) and involves the use of various forms of argument. Informal reasoning is situated within a variety of social and cultural meanings; therefore, it is carried on within different social contexts and applied in different situations. Exploring the use of argument in everyday life as well as in classroom settings is important because an argument implies critique (Mathison, 1995) which allows students to question and make decisions about which specific claims they value in an argument and how they position themselves in relation to them. An important element of critical thinking, according to Dewey's (1909/1991) idea of 'reflective thought', is the use of evidence to support a certain belief or claim.

There are plenty of models about the argumentation process in the literature. But almost all of them take their origins from the work of Toulmin (1958). Evidence is one of the main elements of the model of thinking as argument developed by Toulmin (1958). Toulmin's argumentation model involves six components (Figure 2). According to him; data, warrants and claims are basic and indispensible components of argumentation.

Furthermore, backings, qualifiers, and rebuttals are the components which are the needed components for solidifying the arguments. Briefly; (1) claims are assertions about what exists or values that people hold; (2) data are statements that are used as evidence to support the claim; (3) warrants are statements that explain the relationship of the data to the claim; (4) qualifiers are special conditions under which the claim holds true; (5) backings are underlying assumptions that are often not made explicit; (6) rebuttals are statements that contradict either with the data, warrant, backing or qualifier of an argument (Newton, Driver & Osborne, 1999; Osborne, Erduran & Simon, 2004; Simon et al., 2006; Yackel, 2002).

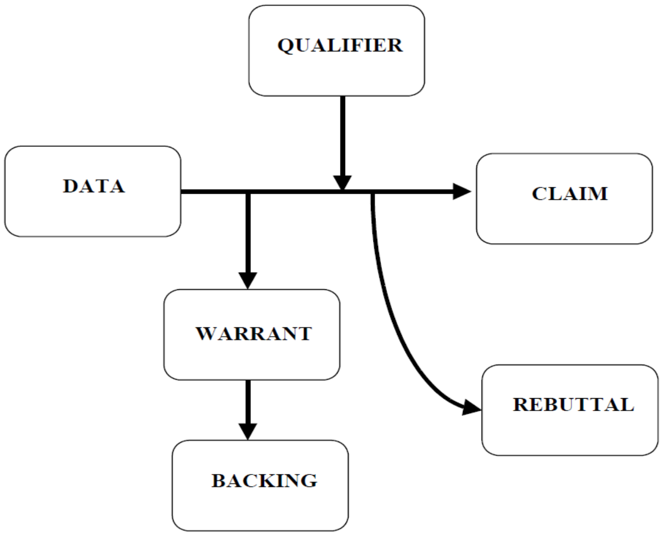

Figure 2. Toulmin's argument pattern (Simon et al., 2006, p.240).

Driver, Newton and Osborne (2000) raised a concern by claiming that Toulmin's scheme presents argumentation in a decontextualized way and "No recognition is given to the interactional aspects of argument as a speech event, of that it is a discourse phenomenon that is influenced by the linguistic and situational contexts in which the specific argument is embedded" (p. 294).

Alternatively, argumentation should be examined and situated within specific contexts while taking into consideration the social framework within it is developed. Argumentation is emphasized in the education literature in two distinctive ways labeled as "rhetorical" (Kuhn, 1992) or "didactic" (Boulter & Gilbert, 1996) and "dialogical" or "multi-voiced". Rhetorical argument is used to persuade others of the strength of the case being put forward while dialogical argument is used when different perspectives are being examined and the purpose is to reach agreement on acceptable claims or courses of action (Driver et al., 2000, p. 291). In other words, dialogic argument is a social activity happening through negotiation. This view is also consistent with Schwab's (1962) idea of presenting science as a product of fluid enquiry and emphasizing science as a process of constructing knowledge situated within specific socio-cultural contexts.

Integrating argumentation into inquiry process

In the literature, the most obscure point maybe the position of argumentation within the inquiry process. Nevertheless, some researchers clearly state that, argumentation brings inquiry to a conclusion based on social agreement (Sampson & Clark, 2008; Langsdorf, 1997). Based on this idea, argumentation can be placed at the end of the inquiry process (Figure 3). As figure 2 shows, inquiry process can be split into two parts. The first part of the inquiry is the "research" and the second part is the "argumentation". In the first part individuals design research, based on a question about a natural phenomenon; then they gather the data, analyze and interpret the data for generating an explanation. In the second part, argumentation, generated explanations are presented to the community and individuals develop arguments to defend their explanations. In this scientific reasoning process, rival ideas are compared. This comparison is made with regard to the strength of the argument to counter arguments. And also warrants and backings of the arguments, reliability of evidence, and association between the evidence and the claim are important discriminators of the arguments.

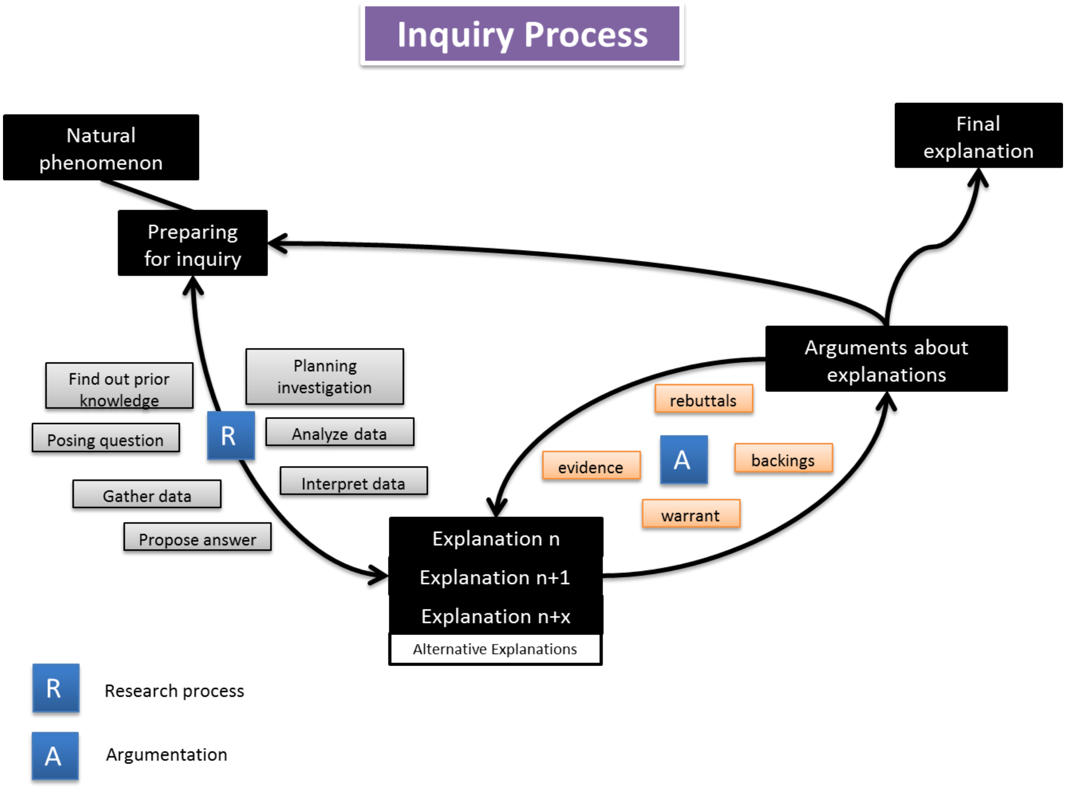

Figure 3. The process of inquiry in school science classrooms.

Our position is that argumentation can be divided into two parts for school science classrooms as well. The first one, internal argumentation, is getting students involved in the scientific inquiry process. That is students undertake investigations and generate explanations about the natural phenomenon and get involved in argumentation. As an example, Cakir (2004) designed an instructional module for prospective teachers to engage them in an inquiry activity in which one of the aims was providing them an insight about inquiry process as future teachers. He used software named Catlab to provide students a teaching and learning environment where they could be able to; gather, analyze, interpret data, and generate and discuss their explanations. During the process, students worked on mono and dihybrid crosses to generate explanations about given scenarios about the coat colors of cats. This genetics-based inquiry process finalized with a classroom discussion that focused on assumptions, predictions, collecting data, evidence, experimental design, and testing alternative explanations. Such inquiry experiences involve both research and argumentation processes together.

The second type of argumentation is Complementary Argumentation where students generate arguments about alternative explanations that have been generated previously. Some studies emphasized the importance of this reasoning process in the case of less accessible information, and more open-ended and debatable socio-scientific issues (e.g. Means & Voss, 1996; Sadler, 2004) such as Global Warming, Nuclear Testing, Animal Testing. The difficulty of experimentation of these ideas in school science classrooms causes the implementation of this "informal reasoning" process. In this instance, students try to defend explanations which are most suitable with their prior knowledge, experiences and their conceptual ecologies.

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THE USE OF LABORATORIES IN SCIENCE TEACHING

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ABSTRACT: Science is one of the significant fields in today's world. It can be described as the process of perception and recognition of the world, thinking about the nature of knowledge, analysis of knowledge and the ways to access information, construction of new information based on the existing one and making estimations about new events. 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 middle and high schools have their physics, chemistry and biology laboratories and universities also have highly specialized versions of them. 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. 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. All these changes in the world also affected in the science education in Turkey. In Turkey, science education program was revised in the years of 1936, 1948, 1968, 1992, 2004 and 2013. According to this arrangement of 2013, the program adopted a holistic approach towards teaching and learning, but it was also accepted that students are responsible for their own learning and active student involvement is needed which requires a constructivist approach. 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. Therefore, studies at laboratories have some certain risks. It requires that at laboratories there should be a safe working environment since workplace laboratories are classified as dangerous. Therefore, staff should know what to do in emergency situations and be aware of potential dangers. In order to provide a safe environment, certain laboratory rules and techniques as well as necessary equipment should be employed. Following such rules is very significant for the health of staff and their safe.

Keywords: laboratory use, laboratory safety, laboratory accidents

INTRODUCTION

SIGNIFICANCE OF SCIENCE TEACHING

Scientific knowledge is the accumulation of the knowledge gained by scholars beginning by the history human beings. People have used it in different forms. This process is considered to be a process of acculturation, which is also called education. It is known that developed societies have well-educated human power. It is widely accepted that effective education is required to produce qualified human power. Therefore, education is considered to be a process of improving individuals' thinking capacity, knowledge base, understanding and skills.

Science is one of the significant fields in today's world. It can be described as the process of perception and recognition of the world, thinking about the nature of knowledge, analysis of knowledge and the ways to access information, construction of new information based on the existing one and making estimations about new events. Science is the result of individuals' attempt to understand the nature and themselves (Collette & Chiapetta, 1989), and is defined as the systematical way of describing the nature and natural events and the attempt to make predictions about the potential events (Turgut et. al., 1997). Science plays a significant role in the development and economic advancement of countries. Therefore, countries put an emphasis on science education in order to keep up with scientific and technological developments to produce individuals who develop knowledge and technology (Ayas, 1995; Ünal, 2003). Therefore, in the last century, countries have attempted to improve the quality of science education. Such attempts are mostly focused on the modification of educational programs (Ayas, 1995; Ayas, Çepni, Akdeniz, 1993). Such changes in educational programs are crucial for the development of countries. Advances in science and technology require that education programs should cover them. At schools, science-related topics are taught in the course of science and technology. Hançer, Şensoy and Yıldırım (2003) argue that one of the basic goals of science education is to produce individuals who can keep up with the changing periods and who could effectively employ all novice technological devices. Another basic goal of science education is to teach individuals that in all technological inventions science is the prerequisite. Science education aims at teaching the ways of thinking and improving the concepts based on experience and the methods of analyzing the cause-effect relationships (Aydoğdu, 1999). Some of the people' motivations to learn about science are as follows:

1) Individuals' desire to learn about themselves,
2) Individuals' desire to learn about their environment,
3) Individuals' desire to arrange the relationships between themselves and their environment,
4) Individuals' desire to deal with difficulties experienced in the world.

Science education is a field which gives 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 (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 middle and high 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 students 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 reasons of these actions are significant scientific findings during war. Questions about laboratory evaluated as how laboratory education is should be. Based on these views, educational programs were revised around 1960's and laboratories began to be part of these programs.

All these changes in the world also affected the science education in Turkey. In Turkey, science education program was revised in the years of 1936, 1948, 1968, 1992, 2004 and 2013. Such revisions began in the period of 1953-1954 in regard to science education at the levels of primary and secondary education. The programs were expanded to include Modern Physics (PSSC-Physica Sciences Study Committee), Modern Chemistry (CHEM-Chemical Education Material Study and CBA Chemical Bond Approach), Modern Mathematics (SMSG-School Mathematics Study Groups) and Modern Biology (BSCS-Biological Science Curriculum Study). These programs also included lab handbooks, teacher guidance materials, movies and materials. Reforms about science programs in western countries initiated at the end of the 1950's began to influence Turkish education system from the 1960's. One of the activities to improve science education was a project named BAYG-E-14 which was developed by science high schools. The project was implemented in nine high schools. It covered several topics including the improvement of laboratory, course and complementary materials, and other teaching and learning materials. In order to use the program improved through the project BAYG-E-14 in much more schools, another project, called BAYG-E-23, was developed. This project was implemented in the period of 1971-1976 on 100 high schools and 89 teacher training schools (Demirbaş, Soylu, 2000).

Modernization studies of the secondary science education ceased and in 1984 were completely disappeared (Çilenti, 1985). Then the Ministry of National Education (MONE) formed several commissions to develop a new science program. It produced textbook-oriented science education (Ayas, Çepni, Akdeniz, 1993). In February 2013, the board of education of the ministry decided that the course was named as science from the school year of 2013-2014 for the fifth grade of elementary education and from the school year of 2014-2015 for the third grade of elementary education. The course would be for three hours for the classes of 3 and 4, and for four hours for the classes of 5 and 8 (MONE-board of education, 2013b). According to this arrangement of 2013, the program adopted a holistic approach towards teaching and learning, but it was also accepted that students are responsible for their own learning and active student involvement is needed which requires a constructivist approach.

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 laboratory work is not at the desired level yet (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 environments, lack of necessary equipment and devices, crowded classes, and teachers' lack of necessary information about teaching and learning materials and about laboratory work. Another factor contributing to low achievement 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; 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). Some of the laboratory accidents occurred in Turkey are given below.

1. Alcohol Burst

21 November 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 elementary 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

2. Tube Explosion at Science Lab, Two Students Wounded.

18 December, 2008

In Kazan, at the science laboratory of Tahsin Şahinkaya elementary 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

3. Thinner Poured Into Stove Killed.

In 2003, a student poured thinner into the stove at the Ortadirek village elementary 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 were 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

4. They Were Burning During Experiment

21 November, 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/

5. Test Tube Exploded: 2 Students Wounded

09 December, 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

6. 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

7. 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

8. Explosion during an Experiment at a Private School: Two Wounded

03 December, 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

9. Explosion at the Laboratory during The Experiment

04 March, 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

10. Explosion at an Elementary Education School: 6 Wounded

04 June, 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; İdin & Aydoğdu, 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 includes 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 experiments' 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 are 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, elementary education should be much more cautious in work at laboratories. At the laboratories of elementary 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 & Candan, 2012).

STEPS TO AVOID ACCIDENTS AT LABORATORIES

As a workplace, laboratories are classified as dangerous. Therefore, staffes should know what to do in emergency situations and be aware of potential dangers. In order to provide a safe environment, certain laboratory rules and techniques as well as necessary equipment should be employed. Following such rules is very significant for the health of staff and their safe.

- At laboratories aprons and gloves should always be used. Protective glasses should also be used. Dress should be proper for laboratory work.

- Laboratories should have fire exits. These should be shown by signs.

–Laboratories should have a good ventilation system. There can be a room next to laboratory which has a ventilation system.

- There should be a fume cupboard at laboratories. It should be placed at a remote place which is far away from doors and ventilation system. In other words, it should be placed where traffic is less. Fume cupboards should be made from materials which are durable against chemicals and steam. These devices should provide a continuous air flow and be ready to be used. Fume cupboards are designed to avoid the effects of hazardous chemicals at laboratories. Standard fume cupboards can be used at laboratories where less hazardous chemicals are employed. At the laboratories where hydrofluoric, perchloric or mineral acids in hot concentration are used, those fume cupboards with higher performance levels are needed.

- A scientific approach should be adopted to provide a safe laboratory environment in order to identify potential and to reduce the possibility of experiencing an accident. A laboratory safety program should be developed to have a safe working environment at laboratories. Such safety programs make it possible to protect from dangers in terms of human health, the storage of chemicals and to avoid accidents at laboratories. Therefore, in order to avoid potential problems, there should be a first-aid kit at laboratories.

- Chemicals that are used in experiments are mostly unhealthy and being familiar with the characteristics of these chemicals is significant for both human health concerns and what to do in emergency situations. Major unhealthy chemicals are as follows: Heavy metals, aromatic nitro compounds, aldehydes, alkali metals, alkali salts (NaOH, KOH), ammonia, benzene, mercury, phenols, carbon tetrachloride, chlorinated hydrocarbons, methyl alcohol, toluene etc.

- Laboratories should always be kept clean. Necessary rules should be followed in cleaning of laboratories.

- While labelling chemicals, the following points should be avoided: using wax pen, water-soluble ink pen, abbreviations, title of the material, formula, and using numbers and codes.

- Chemicals should be stored based on the following rules.

- Removal of wastes
1. Waste materials should be classified based on their chemical characteristics and then, should be removed.
2. These waste materials should be removed in accordance with the groupings written on the waste boxes.
3. Cracked and broken glassware should not be used.
4. Bins with cover should be used to collect flammable waste materials at laboratories.

- At laboratories there should be extinguisher for each fire type and it should be known which fire extinguisher is used for which type of fire.

- Water, electricity, gas, air pipes and their valves should be painted with distinct colours and this system should be shown with a panel at laboratories.

- Electric and gas valves should be known by everyone through signs.

- At laboratories there should be fire blankets to be used in emergency situations.

- Waste materials and dangerous, flammable chemicals that will be used later should be kept at laboratory in small amounts. Following their use, the remaining ones should be immediately stored again. When these materials are poured, they should be cleaned using a proper technique.

- Solvers should never be poured into sink. Waste solutions should be collected in cans and they and trash bins should be discharged every day.

- At laboratories before using fire, the environment should be checked to see if there are flammable objects. Gas or natural gas hose should be frequently checked and they should be changed when necessary. The hose should not contact with the fire.

Laboratory staff should know where main gas valve of the laboratory is. There should be signs to show the place of the main gas valve of the laboratory. In the experiments in which flammable items are used fume cupboards should be employed. Distillation of flammable liquids should be done on sand bath to avoid spreading of fire.

- Fire Extinguishing Equipment should exist in laboratories and in corridors. Laboratory personnel should know where this equipment is and which equipment is used to which type of fire. They should be trained on these topics.

- Soda-Acid Type Fire Extinguishing Equipment: these devices are filled with the solution of sodium bicarbonate and are used to extinguish fire caused by paper, wood etc. They cannot be used to extinguish fire caused by magnesium, sodium and electrical contacts. They can also be used to extinguish fire caused by alcohol and acetone which can be mixed with water, but cannot be used to extinguish fire caused by oil which is not mixed with water.

- Foam Fire Extinguishing Equipment: These devices are mostly used in fire caused by solutions such as oil, gasoline which are lighter than water and do not mix with it. These devices are not used in the environments where electric circuits exist.

- Carbon tetrachloride extinguishers: These devices are used to extinguish small-scale fire. When used in closed places, its steam should not be respired. When fire is totally extinguished, the room should be vented. These devices can be used in the environments where electric circuits exist.

- Methyl Bromide Fire Extinguishing Devices: These devices are used in fire where carbon tetrachloride extinguisher is employed. Given that the steam of these devices is toxic, they should not be used in closed places.

- Carbon Dioxide Fire Extinguishing Equipment: This equipment is used in small-scale fire at laboratories. It can be used in the environments where electric circuits exist. Given that, its cooling effect is at a minimum level following the extinguishing of fire, the material burned should be observed not to flare up again. In fire which is caused by explosive metal such as magnesium graphite or dry salt are employed.

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LESSONS LEARNED AROUND THE BLOCK: AN ANALYSIS OF RESEARCH ON THE IMPACT OF BLOCK SCHEDULING ON SCIENCE TEACHING AND LEARNING

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ABSTRACT: The purpose of this study was to provide a comprehensive review of the literature surrounding block scheduling to better understand what the last twenty years of research reveals about the impact of block scheduling on science teaching and learning. Forty-five selected articles were examined for arguments or reasoning as supporting block scheduling, opposing block scheduling, or stating that block scheduling did not make a difference in the argument. Five categories emerged: 1) organizational issues, 2) curricular issues, 3) instructional issues, 4) learning outcomes, and 5) disciplinary issues. The arguments/reasons were further analyzed into 23 sub categories, with the number of studies for each argument recorded. Data from 31 studies supported, data from 30 studies opposed, and data from 16 studies stated that block scheduling did not make a difference for that argument. Issues associated with block scheduling included school funding, presumed science benefits, teacher retention and student learning outcomes.

Keywords: block scheduling, science education, secondary education, policy

INTRODUCTION

Standards-based instruction and accountability has driven educational reform for many years (Donnelly & Sadler, 2009). The standards movement has sought to quantify students, teachers and schools to a measurable value that can be better understood, rated and ultimately improved. Students, teachers and schools are held accountable by publically acknowledging the measured values. Under the No Child Left Behind (NCLB) federal legislation of 2001, federal grant monies were only given to districts making adequate yearly progress (AYP) towards goals of improvement of their scores. An important subgroup is the low socioeconomic status (SES). School districts are instructed to close the achievement gap so that all students are learning at high levels, producing higher and higher scores. The Every Student Succeeds Act (ESSA) of 2015 shifted control back to the states for closing achievement gaps and advancing equity in the lowest-performing schools (U.S. Department of Education, 2016).

One reform strategy many schools are choosing to utilize to improve student performance on accountability measures is a change in scheduling (Bonner, 2012, Huelskamp, 2014). Block scheduling elongates classes into larger "blocks" of time, usually 90 minutes or more, that meet less frequently (O'Neil, 1995; Zepeda & Mayers, 2006). The concept is not new. As many as 15 percent of junior high and high schools experimented with "flexible modular scheduling" in the 1960s and 1970s before abounding the 20 minute chunks of time modules that could be scheduled to elongate or shorten classes (Bonner, 2012; O'Neil, 1995). When the National Commission on Excellence in Education published *A Nation at Risk* in 1983, "time on task" became a focus of educational reform (Gullatt, 2006; National Commission on Excellence in Education, 1983). Block scheduling was seen as a way to break with traditional and antiquated models and use time in the classroom more efficiently (Bonner, 2012; Dostal, 2010; Gullatt, 2006).

Joseph Carrol published *The Copernican Plan: Restructuring the American High School* in 1990 and the National Education Commission on Time and Learning published *Prisoners of Time* in 1994, increasing interest in block scheduling as a tool for additional reform (Carroll, 1990; Cawelti, 1994; National Education Commission on Time and Learning, 1994). By 2003, 31.8% of all secondary schools in the United States utilized block scheduling (National Center for Education Statistics, 2003). The 31.8% of all secondary schools figure represents 34.5% of all public and 23.6 % of all private secondary schools in the U.S. (National Center for Education Statistics, 2003). Charter schools, available to more easily experiment with time and resources, utilize block scheduling more than other public schools (O'Brien, 2006). In North Carolina, 53.7% of all secondary schools utilized block scheduling in 2003 (National Center for Education Statistics, 2003). Only two states, Maine (56.8%) and Maryland (63.1%), and the District of Columbia (65.8%) had higher percentages of schools on the block schedule than NC in 2003 (National Center for Education Statistics, 2003).

Other countries have also embraced block scheduling, with Canada's British Columbia reporting one third of secondary students studying in blocked scheduled courses in 1990 (Bateson, 1990). Bateson (1990) found that students in the traditional year-long science course outperformed students in block scheduled classes in cognitive domains tests. Absent American push for educational reform, why are other countries moving to block scheduling? Perhaps economic and teacher retention issues come into play. Some school districts have suggested moving to the block as a way to save money in textbook purchases and teacher salaries (Yount, 2010). Although schools that keep class size constant spend more money in block scheduled classes due to the need to hire more teachers (Hamari, 2010).

Whether used to increase standardized test scores, improve student time of engagement, or in saving money, block scheduling does deliver a change to the school day and that draws both praise and criticism. The two most common forms of block scheduling are a 4x4 schedule whereby students take four classes each semester and an AB or an 8x2 schedule whereby students take four classes every other day for the entire school year (Bateson, 2009; O'Neil, 1995; Zepeda & Mayers, 2006).

Reallocating the school day into longer class periods provides opportunities for restructuring teaching methodologies that are more active and therefore increase active student learning in measureable ways (Huelskamp, 2014; Jordan & Padilla, 1999). Block scheduling of classes allows students to take more elective courses in the areas they might otherwise have weak performance (Gullatt, 2006; Queen, Algozzine & Eaddy, 1997) and allows students to repeat a course they failed in the same year without falling behind in their grade level and thus increasing graduation rates (Gullatt, 2006). Block scheduling of classes allows teachers to team teach subjects (Gullatt, 2006; Weller & McLeskey, 2000) and have a larger arsenal of instructional activities (Gullatt, 2006; Jones, 2009; Queen et al., 1997; Weller & McLeskey, 2000). Block scheduling of classes allow administrators flexibilities in scheduling (Queen et al., 1997; Weller & McLeskey, 2000), such as having weaker English students take vocabulary-rich Biology in the spring.

However, blocked schedule courses have less overall instructional time which often means less content is covered (O'Neal, 1995; Queen et al., 1997; Zepeda & Mayers, 2006). Blocked schedule courses meet on half as many days and have half as many breaks between classes which translates into students doing less homework to reinforce concepts (Jones, 2009). Even though block scheduling has been implemented in many secondary schools in the nation, its impact on student learning is still controversial. One often cited method of measuring student learning is a standardized test score. Some studies have found that standardized test scores increased with transition to a block schedule (Trenta & Newman, 2001; Lewis, 2005), some studies have found that standardized test scores decreased with transition to a block schedule (Gruber & Onwuegbuzie, 2001; Harmston, Pliska, Ziomech & Hackman, 2003) and even more studies have found that block scheduling did not make a difference in students' performance as measured by a standardized test (Bonner, 2012; Dostal, 2010; Zepeda & Mayers, 2006).

People in favor of block scheduling often use science classes as a major beneficiary because it allows for more instructional learning activities including laboratory experiments requiring longer periods of time (Gullatt, 2006; Jones, 2009). Research shows science teachers who have transitioned to the block schedule often prefer to stay with block scheduling (Jones, 2009; O'Neal, 1995). Nevertheless, the specific impact of block scheduling on learning environment and student learning in science remain uncertain. Since schools are ultimately held accountable for their government tax dollars, if schools adopt block scheduling, they should have research-based evidence to support it.

In this regard, we conducted a comprehensive literature review to understand what research tells us about the impact of block scheduling on science teaching and learning. By doing so, we can help administrators and educators make informed decisions on scheduling.

METHODS

Selection of the Literature related to Science Teaching and Learning

The literature for this review was selected from *peer-reviewed journals* from 1996-2016 relating to high school science teaching and scheduling type. An electronic search using the search engine EBSCOhost was performed with the search terms "block scheduling" and "high school." The search located about 215 articles that could be possibly included in our review. Next, individual abstracts of the identified articles were carefully reviewed for connections to science teaching and learning. Articles of interest were read to find additional articles. This resulted in the selection of a total of 45 articles for in-depth review for this study.

Analysis of the Literature related to Science Teaching and Learning

The 45 selected articles were coded by their argument/reasoning relating to block scheduling, type of publication, methodology used in research, and the empirical evidence supporting the argument. Arguments themselves were identified as supporting block scheduling, opposing block scheduling, or stating that block scheduling did not make a difference in the argument. All arguments were then contrasted and compared to one another to identify relations across them. As a result, five categories emerged: 1) organizational issues, 2) curricular issues, 3) instructional issues, 4) learning outcomes, and 5) disciplinary issues. Other themes that immerged did not make an argument for or against block scheduling.

FINDINGS

Five themes emerging from our analysis are summarized with the number of studies in Table 1.

Table 1. Categories with empirical evidence

Categories and Subcategories	In favor	Opposed	No difference
1. Instructional Issues			
More variety of instructional activities, including team teaching	5	1	1
Less experiential education activities		1	
Teachers have longer planning periods & fewer class preparations	2		
Fewer minutes of overall instruction in block courses, transition and class management longer		5	
Increase in organization, communication, independent study, homework		4	
Transition difficult for students and teachers		3	
2. Learning Outcomes:			
GPA, academic focus increase	3	1	4
Standardized test, post-test performance	2	5	6
More remediation & enrichment	1	1	
AP classes negatively impacted		1	
Loss of retention between courses		1	
College performance			3
3. Curricular issues:			
Repeat failed course without falling behind in grade level	1		
More courses, more elective course offerings	4	1	
Less material covered		1	
4. Organizational issues			
Student attendance	2	2	2
Scheduling extracurricular activities	1		
More flexibility in scheduling	2		
Students may graduate earlier, transfer process easier	1	1	
5. Disciplinary issues			
Improved school climate	5		
Decreased discipline referrals	2		
Larger class sizes		1	
Student interest diminishes/ students bored		1	
Total:	31	30	16

Support of Block Scheduling

Proponents of block scheduling discuss many favorable aspects such as increased number of instructional activities (Gullatt, 2006), higher grades (Zepeda & Mayers, 2006), flexibility (Queen et al., 1997) and improved school climate (Stader, 2001).

Instructional issues. Because of the longer time periods, block scheduling provides an opportunity for more variety in instructional activities such as cooperative learning, student inquiry and team teaching (Gullatt, 2006; Jones, 2009; Weller & McLeskey, 2000). Jones (2009) found that teachers used a greater variety of assessments, graphic organizers and less student inquiry in study surveying 155 science teachers four years after moving to block scheduling. Teachers teaching on a blocked schedule spend 75% of their time teaching while seven-period day schedule teachers spend 86% of their time teaching (Yount, 2010). Longer planning periods and fewer class preparations (O'Neil, 1995; Queen et al., 1997) could also add to a more positive school climate, increasing teacher retention.

***Learning outcomes*.** Evans, Tokarczyk, Rice, and McCray (2002) reported block scheduling can benefit learning outcomes for high and low achievers by providing opportunities for more remediation and enrichment. Some studies found that students on the block schedule earned higher GPA scores (Lare, Jablondky & Salvaterra, 2002; Zepeda & Mayers, 2006). In a longitudinal study of 500 small, Midwestern high school students, Trenta and Newman (2002) found a statistically significant relationship in the GPA of individual subject areas when students on a block schedule was compared to students on a traditional schedule. Examining standardized test scores, Bonner (2012) found significant gains in African American students taking the biology End Of Course test in North Carolina when on the block schedule. GPA scores could also be higher with an extra elective course provided on the block schedule (Bonner, 2012). Non-core elective courses would circumvent the expectation of reformists reacting to *A Nation at Risk* (National Commission on Excellence in Education, 1983).

***Curricular issues*.** Block scheduling can impact the curriculum in ways helpful to students and administrators. On the 4x4 block, students may repeat a course failed during the first semester during the second semester without falling behind in grade level for the next school year (Gullatt, 2006). Since students take eight total courses on the block schedule, after meeting core course requirements, are allowed to take more courses in general and more elective and accelerated courses (Gullatt, 2006; Queen et al., 1997; Weller & McLeskey, 2000).

***Organizational issues*.** Block scheduling offers more flexibility in scheduling (Queen et al., 1997; Weller & McLeskey, 2000) and provides an opportunity for extra-curricular clubs and activities to meet during the school day rather than after school (Gullatt, 2006). An area of great interest is the impact of block scheduling on student attendance. Two studies found that moving to the block schedule increased student attendance (Jordan & Padilla, 1999; Queen et al., 1997). Queen et al. (1997) collected data of three different North Carolina high schools prior to moving to block scheduling and during the first two years of being on the block schedule.

***Disciplinary issues*.** Administrators have noted a decrease in discipline referrals from teachers when moving to the block schedule (Queen et al., 1997; Stader, 2001). This might be due to a noted improvement in school climate (O'Neil, 1995; Stader, 2001; Weller & McLeskey, 2000). Zepeda and Mayers (2006) analyzed 58 empirical studies of block scheduling in high schools noting that students and teachers liked the block schedule, although their reasons are largely unknown. A major driving force for teachers was having a longer planning period (Jones, 2009). Perhaps a contributing factor for students on the block schedule is that with less course content, blocked classes are described as being easier than traditional classes (Zelkowski, 2010).

Opposition to Block Scheduling

Opponents of block scheduling discuss negative aspects of block scheduling such as less instructional time (Queen et al., 1997) and loss of student attention span (Wilson, Looney, & Stair, 2005).

***Instructional issues*.** Even though there is opportunity for more variety of instructional activities, other factors impact which instructional activities are implemented. There is often less instruction time in blocked courses due to fewer minutes of overall instruction (O'Neil, 1995; Queen et al., 1997), transition time and class management taking longer (Smith, Monnat, & Lounsbery, 2015), and more time needed in class to do what was often completed as homework outside of class (Jordan & Padilla, 1999; Weller & McLeskey, 2000). It is difficult for students to adapt to more activities (Weller & McLeskey, 2000) and it is difficult for teachers to adapt (Harmston et al., 2003). One study found that teachers lectured more on the block schedule (Queen et al., 1997) and one study found that the number of experiential education activities decreased on the block schedule (Wilson et al., 2005). Schools utilizing block scheduling to improve test scores often also proscribe instructional activities with pacing guides and non-inquiry based activities (Scot, 2009).

***Learning outcomes*.** Using standardized tests as a measure, traditional schedule students performed better than block schedule students on standardized tests in science, language arts, social studies and math in Georgia (Gruber & Onwuegbuzie, 2001). Traditional schedule students demonstrated an upward trend nationally in ACT scores while schools on a block schedule experienced a peak near the year of implementation and then leveled out or declined (Harmston et al., 2003). Gullatt (2006) found that block scheduling did not meet the expectations intended for advanced students and Jordan and Padilla (1999) found that lower level students did not perform as well with the fast pace of the block schedule. AP classes were negatively impacted (Gullatt, 2006) and there is loss of retention from one course to the next level (Queen et al., 1997) on a 4x4 block schedule.

***Curricular issues*.** Block scheduling can impact the curriculum in ways that are not helpful to students or administrators. Some schools experienced a limited number of new electives (Queen et al., 1997) because without additional resources, the same number of teachers are teaching the same number of students but in additional courses. Because of the decrease in amount of time in a block schedule course, 12.5% less than a traditional schedule course, less content is covered (Zepeda & Mayers, 2006). Elective courses, often stand-alone courses, might not be impacted as much when less content is covered, but the reduction is content is magnified in core and sequential courses. Jones (2009) found that EOC teachers felt significantly more pressure to cover the curriculum than non EOC teachers on the block schedule.

***Organizational issues*.** Block scheduling increases the need for efficient and effective communication and increases the significance of student absences (Weller & McLeskey, 2000).

***Disciplinary issues*.** Larger class sizes (Smith et al., 2015), concern for relating to bored students and keeping student interest in long 90-minute classes (Wilson et al., 2005) can increase discipline problems. First year block schedule teachers used 11% more time than experienced teachers to manage discipline problems (Queen, Algozzine & Isenhour, 1999).

DISCUSSION AND IMPLICATIONS

We reviewed 45 block scheduling studies published during the past 20 years. Based on the review, we found several issues associated with research on block scheduling. First, arguments for block scheduling often promoted more nonacademic, organizational, discipline and curricular outcomes. This is consistent with Lewis' (2005) study that showed that "block scheduling often results in better nonacademic outcomes than does traditional scheduling," (p. 85). Many studies pointed to changes to school funding without describing how the school budget was changed. For example, increased instructional activities (Jones, 2009) would require additional instructional funding while teachers teaching more students during the year (Wilson et al., 2005) could mean that less funding for teacher salaries is needed. More research is needed on how block scheduling impacts school funding.

Second, science classes were presumed to take advantage of longer time periods in a blocked schedule to do longer laboratory experiments but research found science teachers actually did less laboratory experiments in EOC classes (Jones, 2009) or no difference in teachers instructional practices (Maltese, Dexter, Tai, & Sadler, 2007; Zepeda & Mayers, 2006). More research is needed on how block scheduling specifically impacts science classes.

Third, professional development for teachers has increased in significance in providing fulfilling longer class periods (Biesinger, Crippen & Muis, 2008; Dostal, 2010; Gullatt, 2006; Nichols, 2005). There is a lack empirical data on how professional development has been implemented. In light of vacancies in science teacher positions, more research is needed to understand block scheduling impacts on teacher fulfillment and retention.

Last and most importantly, there is little empirical evidence that block scheduling does advantage learning outcomes. Studies cite the opportunity block scheduling provides for more variety in instructional activities (Gullatt, 2006; Jones, 2009; Weller & McLeskey, 2000) however, block scheduling of classes often creates larger class sizes which cause teachers to resort to traditional lecture and worksheet methods of instruction (Veal & Flinders, 2001). More well-designed empirical studies on the specific impact of block scheduling on student learning outcomes as well as teacher instructional decisions are imperative given that more schools have been implementing block scheduling.

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