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A CASE STUDY ON EFFECTIVE APPROACHES FOR IMPLEMENTING CONSTRUCTIVIST TEACHING STRATEGIES INTO A MATHEMATICS CLASSROOM

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ABSTRACT: *This research study explored the effect of employing constructivist teaching strategies in a mathematics classroom using a single case study design. The resulting analysis and interpretation provided a description of major themes that developed regarding the implementation of a constructivist teaching strategy in a 'traditionally' taught mathematics classroom. Based on the findings, two primary categories emerged with supporting elements that were critical components of each category. These two primary categories represent possible determining factors in effectively facilitating constructivist learning environments. The findings could provide valuable information to an educational learning community considering ways to introduce constructivist teaching to promote student-driven and student-centered learning environments in their schools. It may also provide insight into how this theoretical/philosophical model of learning can be transferred into practice.*

KEYWORDS: Constructivist Pedagogy, Mathematics Education, Teacher Development

INTRODUCTION

In recent years the word "constructivism" has become a buzz word not only in the literature of educational research papers but now a common topic of conversation in schools seeking alternative approaches to teaching and learning. The central idea of constructivism or 'constructivist learning theory' is the belief that learning is an active process where new knowledge is 'constructed' by individuals (and groups) based on prior knowledge and experience. Bruner's (1960) claim that, "any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (p.30) is based on the idea that learning of any complexity can happen, so long as the learner is provided with the proper setting and tools to actively construct and explore the concepts to make sense of it in their own way of thinking. It is under these conditions that the transfer of learning from the educational experience to the "real-world" is believed to be most successful for the learner. The challenge however, lies in the level of expertise and facilitation that is required by teachers in fostering such learning environments for learners to thrive. The social-constructivist paradigm suggests learning in schools is a social process, which involves the negotiation of meaning between student and the teacher or their peers. This suggests that all the things we "know" are a product of our interactions with each other and our own experiences. Recently, there has been a notable growth in interest in social-constructivist approaches to teaching and learning in the mathematics classroom. This may be due in part to the major shift in how we conceptualize mathematical knowledge and mathematics learning (Ellis M.W., Berry R.Q., 2000) shifting the focus from "what" students learn, to "how" students learn.

Influenced by Dewey's (1899) thinking about schooling and society that emphasized the need to harness and provide direction to the child's natural impulse toward activities of learning, this

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new approach in teaching is based on the idea that mathematical knowledge results from students forming models in response to the questions and challenges that come from actively engaging in mathematical concepts and problems that are relevant and meaningful to their own experiences. This is in stark contrast to the 'traditional' approach to mathematics teaching, which treats the mathematics curriculum as a collection of mere facts and skills prescribed from a textbook with very little connection to the real world.

The challenge in teaching using a constructivist approach is creating learning environments that engage and support the learners in developing their own explanations, evaluations, communication, and applications of the mathematical knowledge that they have constructed. Some researchers believe that mathematics teachers almost universally accept that mathematics learning is a constructivist process (Cobb. 1992. p. 3), however despite this understanding, the pedagogical applications of constructivism in math classrooms is extremely rare in schools (Boaler. 1998. p. 42). This could be an indication that while teachers are informed of the theoretical framework of constructivism, there is still very little in the way of support for teachers on how to explicitly facilitate the necessary learning environments in their respective classrooms. Another factor may be the difficulty in measuring the degree in which it is having an effect on actual learning of mathematical concepts. Constructivism works from the premise that constructing meaning and understanding are two sides of the same coin; that in making our own personal constructs and reflecting upon them, we build understanding. (Simmons. 1999. p.174) There are many factors that could contribute to the development of learning environments that support constructivist learning. This single case study research design will investigate the effect of employing constructivist teaching strategies in a mathematics classroom to students whom have not previously been exposed to such experiences. The study will attempt to define some of the characteristics necessary in fostering authentic and autonomous student learning environments.

In search of a strategy for constructivist teaching

While constructivist views of learning have provided a theoretical foundation and framework within which teachers can understand how students learn, it also has posed great challenges to the mathematics education community to develop authentic models of teaching that build on, and that is consistent with, this theoretical perspective. Small group interaction, non-routine problem solving, and manipulative materials can be valuable tools in the hands of mathematics teachers, however the simple use of these tools is not necessarily sufficient to allow teachers to design productive learning situations that result in conceptual understanding. (Simon. 1995. p.140) In order for students to construct deeper understanding of the mathematical concepts they are trying to unpack, they need to be aware of their own learning processes and be able to explain their own thinking to others. (Marks Krpan. 2008. p.6) Marks Krpan (2008) further goes on to suggest that these metacognitive skills and strategies need to be taught explicitly for students to be able to monitor their thinking effectively. This is especially important as a teacher when you consider individual students and the different and unique ways in which they all learn based on their diverging backgrounds and experiences. Among the many strategies that may exist that promote constructivist teaching, this research study will focus particularly on how the explicit teaching of metacognitive skills required to express mathematical processes that are involved in arriving at a solution in their own words, can impact on student learning in a traditionally taught mathematics classroom.

Research Setting

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The research setting for this case study is a large private K-12 school in a quiet neighborhood setting in the south western suburbs of Tokyo with an approximate student population of 1400. In the mainstream section of the school, there are no individualized or special education plans for students that require special needs, instead every student in the class is generally expected to engage in the same learning engagements to meet the expectations set by the teacher. All of the student desks are generally lined up neatly in rows, all facing the front of the room and there is very little opportunity for collaboration between students. For the most part, the teacher dictates the lesson, and the students generally listen and record what is being said. The school is however also an authorised International Baccalaureate (IB) World School in Japan and therefore offers an additional IB course stream in the school that offers a separate bilingual international curriculum and teaching and learning experience that is somewhat different from that of its mainstream counterpart. The student desks are generally arranged in groups/islands, and there is more shared control of the learning environment, where students are allowed to pursue their own inquiries collaboratively with their peers, guided by careful facilitation by their teacher.

The teacher selected for this study, was a high school mathematics teacher hereinafter referred to as 'the *Teacher*' who has experience teaching in both the IB curriculum and the Japanese mainstream curriculum. She has experience with the employment and facilitation of many different teaching strategies that promote student-centered inquiry-based learning. I have worked with this teacher in my capacity as an IB Diploma Programme Coordinator and have observed firsthand her teaching practices in both the IB and Japanese mainstream curriculum. Teaching the IB curriculum comes with expectations for teachers to ensure they are actively facilitating meaningful student learning engagements that are inquiry-based, concept-driven, using differentiated instructions to support all learners, and assessing student performance both formatively and summatively. Development of metacognitive skills is also a key element for success in the IB. To facilitate this, it is necessary for teachers to employ a variety of constructivist teaching strategies to provide opportunities for reflection and understanding of not just what they know, but how and why they know what they know. These are requirements that are made explicit in the IB curriculum documentation. Teachers are also required to continually reflect on their own teaching practices as reflective practitioners, engaging in regular collaborative planning sessions with their colleagues, to ensure that what they teach is relevant, and that they are up-to-date with current practices. When teaching the IB curriculum, the *Teacher* readily employs strategies to promote mathematical discourse and collaborative work amongst students when engaging in math problems. Classes that were composed entirely of lectures on the whiteboard were rarely observed. While she taught the Japanese mainstream mathematics curriculum however, the opposite was observed. The majority of the classes were lecture-based, and there was very little opportunity provided for students to engage in group work, which was interesting to see considering the fact that the *Teacher* had the capacity to facilitate mathematical discourse and collaborative learning engagements in the class.

While it is not explicitly written anywhere, in Japan, based on conversations with teachers in Japan, teachers are generally portrayed as masters of their art, that do not require any further 'learning' to 'improve'. It appears to be an unspoken rule. I have been approached by many teachers to inform me that it is not culturally appropriate to say that a teacher requires 'improvement', as this implies that there is a flaw in the teacher. Not all teachers are grounded in this belief however in Japan teachers are generally considered to be looked up upon as masters of their trade and not to be questioned. In Japan, teachers with different views regarding their profession appear to be the exception, rather than the rule. The *Teacher* selected for this

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case study design can be considered as one of those exceptions, however despite her keenness to try new things and attempt new challenges, much of what she does in the Japanese mainstream classroom appears to conform to the standard traditional transmission approach. Perhaps this 'unspoken rule' that permeates across schools in Japan has been to some extent discouraging her from attempting anything new, or there may be other factors involved. For the purpose of this study, the *Teacher* has been asked to facilitate constructivist teaching strategies in her Japanese mainstream classes at a greater frequency to observe any changes on how it may affect the dynamics of students who are generally accustomed to only the traditional transmission approach of mathematics teaching.

RESEARCH METHOD

Case study research is a qualitative approach in which the investigator explores a real-life, contemporary bounded system (a case) over time, through detailed, in-depth data collection. A case study's unique strength is its ability to work with a variety of sources including observation notes, interviews, curriculum documents, etc. allowing investigators to focus on a 'case' and retain a holistic and real-world perspective (Yin, 2014, p. 4) Purposeful sampling was used for qualitative data collection and analysis, for the purpose of obtaining a deeper understanding of how the new teaching strategy introduced by the selected mathematics teacher has an effect on student learning in the classroom. Qualitative data collection methods that were used include unstructured interviews and direct observation of the teaching in the classroom. Interview protocols were developed that focused on the case study topic using the responsive interviewing model (Rubin & Rubin, 2011). This model was utilized to allow the researcher to formulate a grounded and deeper understanding of what is being studied through the process of following up with previously asked questions, and asking further questions to verify what was initially heard. Semi-structured questions guided the line of inquiry. Every attempt was made to make sure questions were asked in an objective and unbiased manner. For classroom visits, the Marzano Observational Protocol (2011) was used as a guide to focus on specific events occurring in real time during each visit. Detailed notes were recorded on the observation protocol with the date, time and setting recorded for each observation. These classroom observations helped gather further evidence to validate the information obtained during the interviews with the *Teacher*. Follow-up interviews were conducted to address questions that came up during observations that required further clarification.

The interview data was analyzed following the steps outlined by Rubin & Rubin (2011) for responsive interviewing analysis techniques, which began with finding the concepts, themes, events, and topical markers from the interviews; then moving through the process of clarifying and synthesizing the above data units, followed by elaboration, coding and sorting of the data units to support the eventual development of a theory. The purpose of this single case study research is to determine how constructivist teaching strategies that promotes the development of metacognitive skills, have an effect on student learning in a traditionally taught mathematics classroom. The research question(s) that have guided this research process are: How does the implementation of constructive teaching strategies influence change in student dynamics in the classroom? What factors need to be considered when applying constructive teaching strategies in a classroom to provide students with opportunities to support the development of metacognitive skills?

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Research Findings

What was observed from the finding was significantly different from what was expected. It was originally thought that when students were first confronted with the new constructive teaching strategy in a traditionally taught mathematics classroom, there would be some hesitation initially from students in engaging with the sudden change however after a while they would get accustomed to the new expectations and gradually become comfortable with the new learning environment. It was presumed that the classroom culture would to a certain extent 'change' after a few weeks or months of implementing the new strategy in the class in small bits at a time. What was hoped would happen was to see students freely having mathematical discourse with one another on any given problem assigned in class, and communicating the process in which they arrived at the mathematical idea or solution in their own words. It was hoped that we would see more students engaging in focused student-led inquiry in collective groups without the need to always have the *teacher* directly instruct them to engage in the particular task at hand. The findings from the classroom observations however, showed very little change in the way students interacted with one another, and in the way they communicated their ideas and approached mathematical problems with one another. Despite the frequency in which these constructivist teaching strategies were employed to encourage students to have more discourse with one another on their mathematical thought processes, it resulted in little to no change in the overall student dynamics in the classroom. The interviews with the *Teacher* suggest a number of reasons why.

Despite the number of bite–sized group activities to support the development of metacognitive skills that the *Teacher* had carefully prepared so that it has some relevancy with what she lectured on the board, the students seemed to always gravitate back to their original way of 'learning' mathematics when they returned back to their original seating arrangements. This may be an indication that the group activities that were facilitated once or twice a week by the *Teacher* in class were not seen as an integral part of what students considered to be learning in a mathematics classroom. Patterns that surfaced from the collected interview data while searching for the reason why there was no significant change in student dynamics led to the emergence of the following two categories: *Growth Mindset* and *Learning Cultures*. These two categories that emerged from the findings may indicate why there was very little change observed and represent possible determining factors that influence the effectiveness in facilitating constructivist learning environments in a mathematics classroom.

Growth Mindset: An idea that is beginning to gain a lot of favour in educational circles is the notion of fixed versus growth mindsets, and how they might relate to student learning. While this idea continues to be relevant for students, I believe this idea is also relevant for teachers and strongly relates to teacher learning as well. Just like with students, if teachers working in schools do not feel comfortable in challenging new approaches to teaching because they fear failure will reflect negatively on the evaluation of their performance, there will most likely be very little avenue for growth in terms of development on the part of the *Teacher*. Data from interviews with the *Teacher* shows that although she was very keen to try new things, she frequently commented on the pressure of exams causing worrying levels of anxiety on whether the syllabus has been thoroughly covered or not, which discouraged her from spending extended periods of time on group activities. Despite the fact that she and I were aware that many students were often tuned out (sleeping, daydreaming, working on cramming school homework, etc.) during the usual math lectures, she still trudged through saying that it was something she needed to do. When it would come time to engage in a group activity, because

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many were not paying close attention to the lectures or engaged in other work un-related to the class, what was often seen were students just sitting quietly not contributing much in the group activities. Students that were presumably paying more attention in class often lead the discussions, but many of them appeared to be simply going along with what was instructed by the *Teacher*, and not appearing to see the relevance in these activities, and from time to time there were questions raised in class asking what the purpose of these group activities were. Interviews with the *Teacher* confirm that this further increased her anxiety as a teacher and made her second guess the appropriateness and relevance of these activities in Japanese mainstream classes. While this may be a natural reaction from students, at the early stages of implementation, these questions persisted throughout the year. There are many possible reasons for this, however interviews with the *Teacher* shows that this negative student perspective on group activities, may be due in part to it being facilitated as an ornamental add-on, to a lesson, and not having any direct connection with what students view as important such as end of unit tests or end of year examinations. The *Teacher* has admitted that the assigned questions themselves during these structured group activities to promote mathematical discourse were questions they had already seen before, as she feared some students would not be able to engage in the activity otherwise. This may explain why questions regarding the relevance of these activities continued throughout the year. While the *Teacher* may have been keen to try new things, deep down she may not have been totally convinced that these group engagements will support student learning in a Japanese mainstream classroom where the concept of learning mathematics does not involve mathematical discourse. These group activities were thus facilitated superficially and only for a short period of time and only when there was extra time to spare. The decision to keep these activities at a minimum may however be due in part to other external forces that were discouraging her to steer away from the status quo. Perhaps there are more system-wide forces at play outside of the classroom that is causing reluctance amongst teachers to attempt new challenges in Japanese mainstream classrooms.

Learning Cultures: Carol Dweck (2006) suggests that learning is a self-organizing self-initiating process. There is no learning without will on the part of the learner. It's not enough to just introduce a group activity that involves metacognitive thinking to students and assume they will acquire the skill on their own. For learning engagements to have a meaningful impact, it needs to be supported by a solid culture of learning. This culture of learning is something that needs to be developed from the ground up, something that everyone has agreed to do and is expected to do each time they walk into a mathematics classroom. Students will be more encouraged to share knowledge and information this way, commenting and questioning ideas openly and liberally. To do this will require a considerable amount of class time in first cultivating and nurturing the required learning culture. Findings from the interviews and the observations show that there was very little time devoted to developing a learning culture. One possible reason for the lack of time spent may be her unfamiliarity with the concept of what a learning culture is. This is evident, in her repeated approach to facilitate learning engagements using constructive teaching strategies in the traditional 'transmission' culture of the class. Students often looked lost and later off task, which appeared to raise the anxiety levels in the *Teacher* even more. Classroom observations and interview data confirms, that many students in the class had very little in the sense of motivation or 'will' to engage in learning mathematics as well. Many appeared to have struggled in understanding the concepts in mathematics in previous years (and some may have even given up with the struggle altogether) however because it was one of the compulsory courses for University admissions they had no choice but to attend the class. Findings from the teacher interviews also suggests that many teachers in the school view low test scores as having a direct correlation with low mathematical ability, and

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in many cases low test results are used as a tool to motivate students in achieving higher results. While this approach may work for some, there is a fear that some students may slip through the cracks, and after years of being labelled as a low achiever in mathematics, eventually succumb to that label and begin identifying themselves as a student who is physically incapable of understanding mathematics. In either case, the focus is still entirely on the learning outcomes rather than the learning process, the test scores rather than the learners, and in such a climate it would be very difficult to implement any kind of 'culture' that promotes learning that is collaborative with an emphasis on understanding.

Developing a mathematical learning community

One way for a school to support mathematics teachers in fostering a collaborative culture of learning through mathematical discourse in their classrooms is by helping them in building learning communities. For mathematics teachers, a mathematical learning community is a 'community' whereby students are provided with opportunities to actively engage in the making and testing of conjectures, questioning, and providing justification of solutions to problems through genuine discourse with one another. In other words, engaging in a roleplay where all students in the classroom are mathematicians and doing the work of mathematicians. Getting students to engage in genuine discourse about mathematics concepts in these roles however can be very difficult. (Stein. 2007. p.285) One of the reasons I believe is because many teachers subconsciously make it very difficult for students to contribute their own ideas and engage in authentic mathematical discourse. Even when they think they are allowing time for discourse and collaborative thinking in their classroom, a lot of the times it is the teacher asking most of the questions and providing the answers. A certain tone is set in the classroom right from the beginning that treats mathematics as this immense mountain that needs to be climbed, where the only person who knows how to get around it is the teacher. So what students naturally do is to develop ways of mimicking what the teacher is doing, in order to increase their chance at arriving at the correct solutions. And because of this, most of the time it doesn't even matter whether the solution makes any sense to the student or not, as the end goal is to arrive at the correct solution.

Many will identify with the typical ordeal in a traditional math class, where the teacher introduces a new concept or procedure by doing examples on the board while the students take notes; then directs the class through some practice problems; and finally provide time for students to work individually in class or at home on the practice problems. This way of teaching however in many ways cripples students from learning to see any connection of mathematical concepts with their own concepts and understandings they have constructed based on their experiences with the real world. To teach any strategy directly by focusing on the procedures will only cause learners to adopt the procedures and stop thinking. (Fosnot. 2001. p.123) While it is important to understand mathematical algorithms and procedures it cannot be the focus of a math lesson or unit. If our objective is to have students understand and make sense of the mathematics being taught there needs to be more contributions by the students in the classroom. If there are no active contributors in the class, then the priority of the class needs to be put in developing this first, before introducing any new mathematical concepts. If students are to develop any meaningful connections of what they learn in math class with their own experiences, teachers must learn to facilitate strategies that support more student discourse that fosters a community of learners, using supportive motivational discourse with one another to support their thinking, all the while creating a more shared control of the classroom within which students and teachers engage in the process of learning and the constructing of new

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knowledge together. And this needs to be happening in every class, from the moment they enter the room until the lesson is complete.

Some skills need to be taught explicitly to students with appropriate scaffolding in order for the skills to be developed and used effectively in class. Engaging in authentic mathematical discourse I believe is one of these important skills needed to promote the necessary learning community that is required for learning in accordance with constructivist theory to happen. Setting up a 'MathTalk Learning Community', is one way to do this, and it refers to a classroom community in which the teacher and students use discourse to support the mathematical learning of all participants. (Huffered-Ackles, K., Fuson, K., & Sherin, M. 2004. p.82) The key components within a MathTalk Learning Community are: questioning, explaining mathematical thinking, source of mathematical ideas, and responsibility for learning. For each component there are indicators from Levels 0 – 3 that provide guidance to teachers and schools on how effectively the classroom community is being established. The end goal of which is to support a community in which students act in more central or leading roles and shift from a focus on answers to a focus on mathematical thinking. (Huffered-Ackles, K., Fuson, K., & Sherin, M. 2004. p.88) This can alleviate some of the anxiety that may be felt by students who are not confident in mathematics, because all ideas have equal ground for discussion, as the objective of each class is not just to arrive at the final solution, but to be able to explain how they arrived at their solution in their own words.

Inquiry-based approaches offers challenges to stimulate mathematical thinking and creates opportunities for critical reflection on mathematical understanding leading to development of conceptual, relational and principled understandings of mathematics. Through inquiry, learners can go beyond the use and application of algorithms and rules, develop understandings of general relationships in mathematics, and deal with problematic aspects of the abstraction and formalism that is central to mathematics. (Jaworski, 2006. p.199) In a secondary school in South Australia, Sheppard (2008) documents the learning journey that he went through during his first year teaching a group of students from the MAT (Mathematics and Abstract Thinking) program implemented in the school in 2003 using constructivist and inquiry-based approaches to mathematics learning. He compares this experience with his 30 years of teaching mathematics in the traditional way. The course centred on core investigations, with a set of investigative activities that comprised the core work of the course. In a typical week students were given time in class to work on the investigation, but there was also time allocated for 'unseen orals' which were a set of examination style problems that were assigned to groups to solve. The group members were required to try and solve it individually at first but then given time to discuss their solutions with the other group members and then present and justify their solution to the other group members. Other groups were assigned different questions and they presented their solutions to each other in this way. The remaining time was spent working on their investigations followed by a quiz at the end of the week to give students the opportunity to check on their understanding of and ability to apply the concepts involved in the week's activities and at the end of the topic there was a test. (Sheppard. 2008. p.54) This particular class was an Year 12 class which is considered to be a very intensive year in terms of content coverage and exam preparation, however the different approach to mathematics teaching and learning did not appear to affect the students stress levels or TER (Tertiary Entry Rank) results. In fact, he concludes that he felt as a result of the approaches adopted in the class, the students were much better prepared for further study and had more positive attitudes to themselves as learners. The author highlights how much of an important learning experience this was for himself as well, who now sees his role as a teacher to increasingly 'work' more with others

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rather than 'tell' others what to do, and in the process becoming more of a facilitator of learning rather than a transmitter of knowledge. (Sheppard. 2008. p.57)

Research Implications

Returning back to the original research questions, the findings from this research suggests that the simple employment or implementation of constructive teaching strategies in a classroom do not necessarily influence change in a class that has not been previously been exposed to these new learning experiences. The *Teacher*'s facilitation of constructivist teaching strategies in her IB class did not appear very different from what she facilitated in the Japanese mainstream class, however there were clear differences in the way in which the students from the different classes responded and engaged in the group activities. The students in the IB classes quickly responded to her instructions and engaged in discussion amongst each other in the desired way, however in the Japanese mainstream class the engagement between the students always appeared contrived and never really changed regardless of the frequency in which it was facilitated in the class. This may imply that for new initiatives to be trialled and to take new shape in the classroom, simple implementation of a teaching strategy alone may not be sufficient. What may be required prior to implementing a constructivist teaching strategy is the cultivation of a 'learning culture' where student input and collaboration is valued as an important component of learning in a classroom. This 'learning culture' can also benefit teachers as well, by providing opportunities to continuously reflect on their current practices and continue to grow as learners. Unless schools and administrators begin to consider ways to nurture this necessary 'growth mindset' in teachers to support their ongoing professional development, the hurdle may be too high for any single teacher to clear to become effective change agents in their schools, as was the case for the *Teacher* in this research study.

Given the circumstances of the *Teacher* and the students in the Japanese mainstream class, this research suggests that regardless of what new constructivist teaching strategies are introduced/continuously employed in a classroom, if they are not employed within an established 'learning culture' and/or if the teacher is not supported within a work environment that will allow them to develop a 'growth mindset', it will do little to effect any change, and consequently unlikely to provide opportunities for students to have any kind of meaningful mathematical discourse in the classroom. At this stage however it is still unclear what the necessary conditions are in developing this required 'growth mindset' in teachers, or to establish, strengthen, and sustain a 'learning culture' in a mathematics classroom. Careful examination of these determining factors can contribute to important areas for future research.

CONCLUSION

If mathematics education is comprised primarily of rules and procedures to be memorized, it makes the discipline not only extremely difficult to follow but increasingly less sense to students as they move up in academic years. Mathematics is commonly associated with certainty, with "knowing it", and with being able to "get the right answer quickly". However if these cultural assumptions are reiterated daily in the experience that students have in schools, where they are asked to follow rules set by their teachers and demonstrate that they can memorize and apply a rule when asked to, as Fosnot (2001) previously noted, students 'stop thinking'. Clearly, if as Wathall (2016) suggests, we want to teach for understanding, and focus more on the 'how' they learn, as opposed to the 'what' they learn, alternative approaches in

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teaching needs to be considered. The constructivist view of education has at its focus, prior knowledge or existing mental frameworks of each individual as the necessary tool in nurturing conceptual understanding through social interactions. It is based on the idea that conceptual knowledge is not something that can be attained by passively receiving it through the senses or via any form of communication, but is a product of a series of moments where pre-existing ideas are put forth and challenged by pre-existing ideas from other individuals and then actively built up and created from within. The implications of this when teaching mathematics is that when new mathematical concepts are introduced, students need to be provided with opportunities to reflect on and recognize the mathematical knowledge as a social construction, and through the investigation of real examples of the application of mathematics, to gain insight into the relationships between mathematics and societal, environmental ethical and other real world factors. One of the underlying difficulties with 'constructivist teaching' is that there are no prescribed strategies in teaching in a constructivist way. What is needed is a new pedagogical understanding on how to foster the necessary environments needed for constructivist teaching and learning to thrive. Based on the belief that all knowledge is constructed by the individual through social interactions, teachers can and do create environments, in which students' mathematical knowledge-building and understanding is fostered. (Pirie, Kieren. 1992. p.506) All that may be required is a simple switch in perspective of the role of a teacher, from that of a gatekeeper of knowledge to a facilitator of learning, but what is still not clear is the mechanism responsible for triggering this switch.

The promotion of inquiry-based investigative approaches and MathTalk Learning Communities in the classroom are just a few strategies a teacher can consider during their lesson planning when attempting to incorporate a learning model that is consistent with constructivist theory. An important point to note here is that it should not be treated as a supplementary activity to facilitate at the end or beginning of a lesson, rather it should comprise the whole of teaching. The teacher must also continue to consider oneself as a learner alongside the students they teach, as a member of a learning community. They should be mindful of the fact that they are always constructing new knowledge and developing new understanding of how their students learn mathematics after each taught lesson in the class. In this respect, constructivist teachers can be also considered as contemplative practitioners, teaching with more presence, focused attention, and with greater care regarding the learning that is happening within each individual student and within oneself. While it cannot be clearly determined at this stage what factors are involved in developing 'teacher learners' that can facilitate effective constructivist learning strategies within an established learning culture, what can be concluded from this research is that, as a school if we want to develop mathematics teachers that can foster real mathematical thinking and problem-solving within our students, it is necessary to provide opportunities for mathematics teachers to make mistakes and not be evaluated negatively by it, but rather to be able to learn and improve from the experience through ongoing constructive feedback from their colleagues and supervisors. They also need to experience firsthand this type of learning as well, (in the same way as experienced by Sheppard) to allow for time to reflect on and prepare mentally for the changes they perceive as necessary in order to create the kinds of interactions fundamental to constructivist teaching, (Simmons.1999. p.195) but also in the process, to be open to the changes that will inevitably happen in their own self as a teacher and their perception of what constitutes as good mathematics teaching.

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