Essential Ingredients that form the basis for Mathematical Learning: What has 20 years of teaching mathematics to teenagers taught me?

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Abstract
Educators strive to improve student learning outcomes and there are numerous theories suggesting how this is best achieved. However, application of these theories to the coal face of a classroom is often fraught with obstacles resulting in poor outcomes. Constraints imposed by educational policy, school systems, structures and the individual students themselves, realistically require adaptation of theoretical techniques if genuine learning is to be imparted to students. This paper discusses some of the issues surrounding the practical implementation of new methodologies into the classroom and identifies important factors that affect teenagers in their learning of mathematics.
Working within the constraints, constantly confronted with obstacles, can be frustrating and demoralising. This paper reflects on twenty years of classroom teaching of mathematics to students with relatively poor socio-economic backgrounds and the lessons learnt from them that may assist teachers to remain enthusiastic and creative with the energy to truly improve mathematics education. Key issues explored in the paper include: 'Realities of a teacher's working day', 'The learning of mathematics within a government secondary system', and 'What can be done to ensure mathematical learning takes place?'

Keywords Mathematics, learning, teaching methodology, teenagers

Disclaimer The opinion and comments presented in this paper represent those of the author and do not necessarily reflect the view of the Department of Education and Early Childhood Development in Victoria.

Introduction

Those passionate and dedicated to the development of mathematics education and the teaching/learning of mathematics, are constantly seeking for better ways to engage and teach the students entrusted to them. Our world is not static, new technologies, new things are constantly being discovered and educators must continue to be learners and embrace the changes occurring around them.

The temptation, however, to lose sight of some fundamental realities faced by many teachers in the classroom and to focus on the methodology and learning tools only, is very real. Educators should be wary of not letting the methodology or new technology cloud their perspective on the reality of each individual situation.

There are many obstacles and constraints a teacher faces in attempting to successfully engage and improve student learning. These detract from the optimum teaching/learning outcomes.

By reflecting on personal experience and observation over a period of twenty years of teaching mathematics to teenagers with relatively poor socio-economic backgrounds, this paper discusses some of the practical issues surrounding the implementation of methodologies into the classroom and some of the findings made.

Key factors contributing to the successful teaching/learning of mathematics are identified and strategies for managing and coping with the constraints and obstacles encountered are suggested.

Context

It is important to clarify from the outset that the students and school system referred to in this paper relate largely to what is considered to be an under privileged area in the Western suburbs of the City of Melbourne, Australia. Non professional occupations and relatively high unemployment characterise the socio-economic status of many of the parents. Thus, the situations encountered and discussed do not necessarily reflect the experience of all Victorian Government schools.

Over the last twenty years, many new ideas, educational methods, reporting systems, assessment procedures and overall strategies for teaching mathematics have come and gone. Methodologies and approaches to the teaching and learning of mathematics have constantly changed and many of these changes have been imposed on teachers within the government system.

Teachers have been encouraged to modify their practices and incorporate new teaching tools such as mind maps, graphic organisers and the like into their daily teaching. There have been suggestions to cease using numerical marking schemes and to use rubrics in order to more accurately measure deep

learning. Project work involving lengthy reports that summarise and analyse certain situations and problem solving tasks have all been emphasised at different periods of time. Group work and the discovery of theorems/formulas from first principles along with a shift away from simply 'drilling' a skill have all been considered innovative and conducive to learning. In recent times, funding has been made available to those schools who demonstrate the use of integrated projects. The list could go on, and by naming some of the innovations no value judgement is being placed on them, but rather attention is being drawn to the fact that governments and educators over the years are fully aware that there is improvement to be made in the way students are educated and they have therefore been proactive in promoting new alternatives.

Realities of a teacher's working day

There is diversity in the ways schools function. However, there are many common experiences that are shared, e.g. the demands placed on teachers' use of time. Numerous meetings rob valuable time to prepare, correct and provide detailed feedback on student work. Many activities require specific setting up of rooms. These rooms are often being used by others for a different purpose and are therefore not available to be set up in time. Timetabling often places geographic constraints on teachers resulting in them rushing from one end of a school to the other, unable to meet the expected schedule. Carrying equipment (concrete materials are seen as very important especially in catering for the slower learner) to different venues can be hazardous. The preparation of materials and resources in themselves can be incredibly time consuming and expensive.

The use of IT has been assigned high priority in recent years, and students actively engaged in valuable learning activities using such technology is a situation that is highly rated. Unfortunately, the reliability of the technology functioning well is not guaranteed. How many times have teachers encountered the problem of them not working, just when they are needed or students have forgotten their passwords or run out of internet credits? Added to this is the continual frustration of limited access to computers. Often, software that was working beautifully the day before suddenly decides to play up and a teacher is frantically trying to rectify the problem whilst twenty five boisterous students are interjecting with 'helpful' advice or maybe just creating havoc.

So far, some of the physical components that can be the obstacles that hinder the successful implementation of a plan have been mentioned but what about the students themselves? What a collection of different tales enter the room every time a class of students appear.

"Miss, I've got a headache", "Sir, I've lost my book", "Miss, I don't have a calculator", "Miss, I've been away and don't know what to do", "Sir, I have to leave in fifteen minutes...."

So often, activities are made up of different parts that depend on each other so that when one component is missed it creates a missing link for subsequent sections. This becomes an issue for a student who has been absent. Activities often assume an interested, engaged and motivated student entering a classroom expecting to work, concentrate and learn (provided the material is stimulating and creative of course) but so often the reality is different and instead a teacher is confronted with non educational issues that are of much greater importance to the student than the learning of mathematics. Teachers are believers in education and place it high in their order of priorities, however, for many of the students, problems with friendships/relationships, chaos or instability at home, loom as much larger priorities and their emotional and overall mental state as they enter the classrooms impose far greater hurdles and obstacles for learning than teachers can often imagine. It should also be remembered that students, especially teenagers are not necessarily consistent in their receptiveness from one day to the next or even from one hour to the next. Therefore, when new methodologies and ideas are enthusiastically embraced, the many practical constraints that may influence the successful implementation thereof must be carefully taken into consideration.

The learning of Mathematics within the secondary school system

Regardless of all the constraints and obstacles encountered, teachers somehow manage to work around them and adjust as best they can to the situations they find themselves in. However, one particularly disturbing observation has caused a questioning of the emphasis placed on teaching methodology and teaching tools, to emerge.

With all of the improved awareness and consciousness of best practice when it comes to teaching/learning, one would expect significantly improved outcomes in student learning over the years. Sadly, this has not been evident. Instead the school has been confronted with the reality that those who have entered the secondary system with weak mathematics skills rarely show significant improvement in their six years of post primary schooling and leave with equally poor skills. (Note: In Victoria, children begin their formal education at primary

school where they complete seven years before entering the secondary system). Students maybe demonstrate some mathematical skills at various times throughout those six years, but these skills are quickly forgotten and real mathematical learning/progress has not been achieved. This experience is supported by recent research that indicates that 80% of students who enter the secondary system with weak mathematics skills (in the poorer regions of Melbourne) continue to struggle with their numeracy skills and don't improve as they move through secondary school.[1]

Conversely, those entering the system with good mathematical skills, continue to develop and make good progress irrespective of the methodology or learning tools encountered.

This is disturbing in that it suggests that mathematical learning, when it concerns teenagers, is not as strongly linked to methodology as many would have liked to think and that there are actually other important factors that contribute to successful learning. It also gives rise to the question of why some students continue to progress while others continue to fall behind even though exposed to the same material.

If important concepts such as ratio/proportion, multiplicative thinking, place value, decimals and fractions along with fundamental number facts (e.g. times tables, grouping of numbers in 10s, i.e. 2 + 8 = 10) are not in place or haven't been fully understood when students enter the secondary system, their future mathematical learning and development is severely hindered. The lack of these concepts means that there are no sound foundation blocks upon which to build and the whole mathematical learning structure remains shaky. To complicate matters, these students have often already developed a strong sense of failure with enormous 'blockages' towards mathematics learning due to seven years of previous unsuccessful exposure to mathematics. It is like a foreign language shrouded in mystical terms that have no meaning and continue to have no meaning. Avoidance and strong disguising mechanisms that protect these students from embarrassing themselves in front of their peers and also their parents and teachers make it difficult to address these deficiencies openly and so these students blunder their way through the system using different strategies like working hard at obtaining results from others, copying answers, simply modelling off examples without understanding the reasons why certain processes are being applied or simply convincing themselves that all mathematics is stupid and irrelevant and only for 'nerds'. With this mindset firmly ingrained, any activity no matter how exciting or innovative will struggle to positively engage and shift the learning momentum. No wonder, when these students are tested, using internal or external material, and left to their own resources, the results are poor. The temptation is to lay blame with the teachers and to grasp hold of the easy scapegoat 'Methodology' and focus on doing things differently. I.e. there must be something wrong with the way the material is being presented. It is interesting to note, that many of society's revered athletes, reach their level of success and performance through hard work, repetition and practice. E.g. a swimmer will endure hours of endless (seemingly boring) training swimming back and forwards in a swimming pool or a marathon runner will run endless kilometres enduring severe pain. It appears the overriding factor is not in the training model itself but rather with the person committed to a goal. In other words, a person will persevere and push themselves to improve if they see some intrinsic value therein or alternatively have a goal in mind that they are determined to achieve. For mathematics learning to take place, the student must see value in what it is he/she is involved in and also believe in their own ability to be able to succeed. Without these basic ingredients progress will always be hampered.

Improving mathematical learning

Before embarking on the question of what can be done to ensure mathematical learning will take place, the context within which this question is being addressed must be made clear. Mathematical learning can take on many different meanings and one needs to be clear what the aims actually are. Improvement of mathematics education worldwide embraces an enormous range of ability levels and cliental. For example, in aiming to improve mathematics education, the teaching of calculus to every student would not be deemed appropriate, so when working within a general statement like 'Improving mathematics education or mathematical learning' the cliental base needs to be specified since the aims and expectations will not be the same for everyone.

This discussion focuses on the mathematically low skilled teenager with relatively poor socio-economic background that attends a government secondary school in an under privileged area. The above discourse has briefly touched on:

(i) The fact that governments and those involved in education have been and continue to be proactive in improving mathematics education
(ii) Some of the practical constraints faced by teachers in their daily quest to successfully educate
(iii) The observation that the secondary system in its current form is not meeting the needs of the mathematically low skilled teenager as he/she passes through the system

It is at this point that one could be feeling largely deflated and somewhat despondent if working in a similar environment as described above. So how does one rise above the obstacles and remain enthusiastic, energetic and proactive for positive change?

[1] Farrah Tomazin and Carol Nader, 'Poor children less likely to improve through school', *The Age*, 18 April 2009, p.1.

The secret lies in the recognition of the key ingredients that form the basis of mathematical learning. It enables one to see past the actual teaching hazards and obstacles and puts them in a different perspective. Knowing that students can learn well in spite of their relatively poor resources and underprivileged status gives hope in what may often seem a hopeless situation.

So what are these essential ingredients? In the case of mathematics, a student needs:

(i) The fundamental concepts, as mentioned above, e.g. ratio/proportion to be in place. From this basis, further mathematical knowledge can be built. If these concepts have not been understood, sitting in mathematics classes for a further six years will not yield positive results, irrespective of the methodology. It is critical therefore that a student is brought to this realisation and by developing trust and confidence in the teacher has the courage to confront his/her low skills and go right back to the start. Ideally those responsible for the development of curriculum should devise a suitable course that addresses these fundamentals in an appropriate way that is suitable for teenagers as opposed to young children.

(ii) To see intrinsic value and purpose in learning mathematics. If he/she can make important links between the different areas and see how they connect with his/her current experience of the world, then motivation comes naturally.

(iii) To believe in his/her own ability to succeed in mathematics. This presents a huge challenge in that it involves a change of an already established mindset. Years of negative influences need to be undone in order to create a positive frame of mind, open to and keen to understand the language of mathematics.

Once these key ingredients are present, the basis for learning and progress is there and growth will occur with relative ease. Unfortunately these key ingredients require a huge investment in human time. I.e. they cannot be easily rectified by written programs or external mechanisms but rather require intensive human intervention. As stated previously, teachers need time to spend with these students. Teachers need time to thoroughly prepare and provide feedback on student work on a regular frequent basis and to attend to the individual needs of each student. Students feel valued and respond accordingly when they sense there is a genuine interest in their welfare. Governments and educators when addressing the short comings of low achieving students in the secondary system need to resist the temptation to blame the work force or methodology and rather be proactive in channelling significant human resources to those in the classroom.

So what can be done now within the constraints of the systems teachers work in?

Remember at all times that each student is an individual person with their own tale to tell and take the time to develop a positive relationship built on trust. Human beings learn and function best within positive relationships. Never lose sight of the fact that teenagers are potentially fragile beings who can't be expected to think and function like mature adults, but have the potential to be both delightful and vibrant. Be willing to put everything into context and continue to let the students know both why there is value in learning whatever is being presented and why it is important in today's society. Always prepare an activity with the question "What is being learnt here?" or "What learning value is there in this activity?" in mind. Consider the cliental before blindly applying someone else's idea and question the basic assumptions underlying the 'idea'. Be conscious of the fact that with every student there is the potential to create a spark and love for mathematics but be realistic in acknowledging that not everyone is going to love mathematics.

In an ideal world, there would be endless resources, endless time and opportunity to work with individuals and produce mathematically competent adults across all regions of the world, however, that is not reality. It remains important that teachers strive to improve their teaching strategies, constantly being prepared for change and innovations but at the same time keeping a true and realistic perspective on their own situation and how it can best be improved.

Conclusion

The tools used in the teaching of mathematics and the methodologies practiced by teachers do not stay the same. In twenty years of being in the classroom, many changes have been trialled. Teenagers in the secondary school system will make progress in their mathematical learning, if the concepts of ratio/proportion, multiplicative thinking, place value, decimals and fractions plus fundamental number facts such as times tables and grouping numbers in 10s are in place, and if their mindset is positive and they see purpose and value in the learning of mathematics. Without these key factors, methodologies or new innovative ideas are not likely to have a significant impact on the learning.

Being aware of the conditions under which a student learns, helps identify the appropriate strategies that will best aid the student in the quest for improved learning outcomes and gives renewed energy to a teacher despite the many constraints encountered. There is always a way forward, no matter how small the steps may be, once the direction is known. It is critical to understand and be realistic about each individual circumstance and to always be mindful of the human factor that plays a large role in the education process.