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Unravelling the Myth of Effective Teaching in Mathematics

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Abstract

Effective teaching is the backbone of any successful education system with many arguing that it is the single biggest contributor to student success. However despite such importance, significant differences in teacher effectiveness are still evident in Irish classrooms at all levels of education. This research investigates the influence that individual teachers can have on students' enjoyment of mathematics at second level and attempts to unravel the myth of effective teaching. The research started out as a follow-on study that further analysed data collected by the authors when they designed a pedagogical framework with the aim of promoting student interest in algebra through effective teaching of the domain. This paper focuses entirely upon the quantitative results of the evaluation of that study with regard to whether there are differences in the enjoyment scores of students' in different classes as a result of their individual teachers. The paper also looks to unravel the myth of effective teaching through a series of focus group interviews and a detailed literature review.

Keywords: effective teaching, enjoyment scale, mathematics education, quantitative, second level

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Introduction

Effective teaching at all levels is the backbone of any successful education system. There are many similarities between teaching at second level and at third level, particularly in the introductory years. However, Childs (2010) argues that teaching at second level is a more demanding job as there are less experienced learners and usually, a wider range of ability and interests. Undergraduate student populations also tend to be more selective in both ability and interest (Childs, 2010). Hence this study will investigate teacher effectiveness at second level in order to consider a greater scope of the phenomenon. However the findings will undoubtedly be of interest to third level lecturers as there is a great amount of commonality in what makes an effective teacher, regardless of level.

The importance of effective teaching is recognised throughout the literature. Tarr *et al.* (2006) asserts that at the heart of quality education is quality teaching. In the U.S.A., the National Council for Teachers of Mathematics (NCTM) (2000, p.21) identify that "the kind of experiences teachers provide play a major role in determining the extent and quality of student learning". In addition both Sanders' (1999) and Wenglinsky's (2000) work asserted that teacher effectiveness is the single biggest contributor to student success. Sanders, Wright & Horn (1997, p.3), also concluded that successive years with effective teachers created "an extreme educational advantage". However, effective teaching does not just have advantages in terms of student success. It can make the classroom a more fun and enjoyable place (Gourneau, 2005). Furthermore, effective teachers with their own unique personas and traits can exercise a wholesome and inspiring influence on their students.

Defining an Effective Teacher

The concept of an effective mathematics teacher is a problematic one. Papanastasiou (1999, p.6) stated "that no single teacher attribute or characteristic is adequate to define an effective teacher". This view is conceived from the fact that the instructional criteria differ for every situation and for every teacher. Each teacher also brings their own experiences, skills, knowledge and personality into the classroom. Furthermore good teachers make teaching look effortless and this makes the nature of their underlying knowledge and skill hard to pin down (Fox, 2005). Hence, many educators believe that a greater insight is gained, simply by listing the characteristics of an effective teacher, rather than having to dismantle complex definitions. There are an abundance of lists offered throughout the literature of what constitutes effective teaching (Sullivan, 2001; Young, 2006, Childs, 2010). All of these lists focus on a diverse range of practices such as lesson preparation and delivery, evaluations such as assessment and feedback, and characteristics such as patience and professionalism. Although each list is undoubtedly effective in theory, research suggests that this does not transfer in practice. An Irish study carried out by Morgan & Morris (1999) found that the clear majority (87%) of students across all participating schools felt that some teachers teach better than others. Smyth *et al.* (2006) investigated this further and offered an insight into the characteristics which Irish second year (13-14 year old) students felt contributed to effective teaching. During this study, students were asked about the teacher characteristics that helped them to learn best, as effective teaching should result in effective learning. Figure 1 shows the results of the survey.

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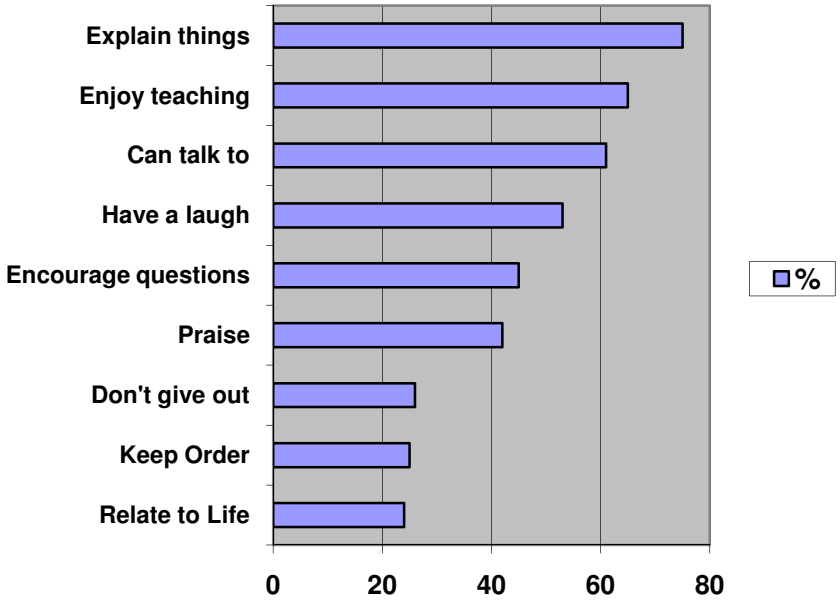


Figure 1 Teacher Characteristics (% 'very important') of Effective Teaching

Symth *et al.* (2006, p.120)

The majority of students noted 'teachers enjoying teaching the subject', 'being able to talk to teachers' and 'being able to have a laugh with teachers' as important qualities. However the single frequently mentioned aspect was the 'teachers' ability to explain the subject or topic to students (Symth *et al.,* 2006). In a different study carried out by Backhouse *et al.* (1992, p.6), a student declared "a good maths teacher is one who can understand your problem fully and does not get angry if they have to explain it a few times". In order to do this, a teacher will make use of a range of important skills and characteristics such as their attitude and expectations, their teaching style and their subject knowledge. Each of these will now be examined in more detail.

Teachers' Attitudes and Expectations

Teaching has been described as an intensely psychological process (Watson, 2003). It can be a demanding profession that often entails a heavy workload and teaching of some disruptive

students. Therefore a teacher's ability to perform effectively in their profession often depends on their personal qualities and their ability to create individual relationships with others. This ultimately comes down to the attitudes employed by each specific teacher. In keeping with Kyriacou (1998), the manner and attitude with which you carry out a particular task is just as important as the task itself. For example asking a question with interest and enthusiasm conveyed in your tone and facial expression, as opposed to sounding tired and bored, makes a difference to the response you get. Gourneau (2005, p.1) discussed five main attitudes and actions which in his opinion summed up effective teaching. They included;

- A genuine caring and kindness of the teacher
- A willingness to share the responsibility involved in a classroom
- A sincere sensitivity to the students' diversity
- A motivation to provide meaningful learning experiences for all students, and
- An enthusiasm for stimulating the students' creativity.

Each of these attitudes if demonstrated successfully by the teacher can leave lasting impressions on students and contribute to a positive learning environment in the classroom. Midgley, Feldlaufer & Eccles (1989) also demonstrated that a teacher's attitude has a strong relationship with students' attitudes about mathematics. For example, if a teacher perceives an area of mathematics as straightforward and trouble free, then it is likely than students will respond the same. This is also linked with teacher's expectations. Studies carried out show the importance of high expectations as the basis of effective teaching and learning (Joyce *et al.*, 1999; Teddlie & Reynolds, 2000, as cited in Glover & Law, 2002). Teachers' expectations of their students can become a self fulfilling prophecy. Students that teachers expect to do well, tend to achieve better, while students who are expected to do badly, usually tend to fulfil these expectations as well (Muijs & Reynolds, 2001). While it is often the case that teachers have accurate expectations based on their students' ability, many expectations

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are biased. For example in a study carried out by Tiedemann (2000), mathematics teachers were asked to consider boys and girls achievement in the mathematics classroom. Teachers thought that their average achieving girls were less talented than equally achieving boys. Girls were thought to exert relatively more effort to achieve success while boys' success was attributed to ability. Teachers also rated mathematics as more difficult for average achieving girls than for equally achieving boys. This study by Tiedemann is a prime example of the biased expectations often held by teachers.

Teaching Styles and Methods

Each individual teacher will have their own styles and methods for delivery. Such diversity is backed up by Cockcroft (1982), who established that there is no definite style for the teaching of mathematics. However, research carried out by the NCCA (2005b) describes the majority of mathematics teaching in Ireland as procedural in fashion and highly didactic. There is a formal, behaviourist style evident (Morgan & Morris, 1999). Lessons are dominated by 'talk and chalk' (NCCA, 2005a) and mathematics is presented as the replication of procedures demonstrated by the teacher (Brown *et al*., 1990; Cobb *et al*., 1992). As evidenced by Dossey (1992), this dysfunctional approach results in students learning the 'how' rather than the 'why' of mathematics'.

The introduction of 'Project Maths' in Ireland aims to promote a more informal approach to the teaching of mathematics. In contrast to the traditional teaching approach, an informal style focuses on developing within all students, a concrete understanding of mathematics. The style is synonymous with a constructivist approach in which activities are student centred, giving them more control and direction over their work (Kyriacou, 1998). These activities attempt to increase the use of practical work and concrete materials in which concepts are

explored and procedures are reflected upon. Although this may take many teachers outside their comfort zone, it leads to situations where students have to draw upon their own initiatives, knowledge and problem solving skills. It is also important that effective teachers ensure that the mathematics taught has a relevance to real life and is taught in context (NCCA, 2005b). Unfortunately the traditional public image advocates that "mathematics is a highly cerebral activity, far removed from the practical realities of daily life" (Harris, 1997, p.171). At every available opportunity, teachers must dismantle this image by making connections to real life situations using up to date examples and resources. This requires teachers to be fully competent in their own subject knowledge. Teachers with a broad and integrated knowledge of mathematics are more likely to be able to use a variety of teaching approaches and styles (Irwin & Britt, 1999). However, such competence in subject knowledge amongst mathematics teachers is problematic of late. A study carried out by Post *et al.* (1991) found that many teachers simply do not know enough mathematics.

Teachers' Subject Knowledge

The informal approach of teaching mathematics which was promoted in the previous section requires a much firmer knowledge of mathematics (Askey, 1999). Teachers are not restricted by use of the textbook and are more likely to step outside the comfort zone of didactic teaching. When knowledge is restricted to what is in the text, the teacher will frequently be at a loss when students come up with an answer or method different to the one provided. In addition, firm subject knowledge allows the teacher to make subtle connections between different elements of mathematics and indeed other subject areas (Smith, 2004). This is very important especially when showing the relevance of mathematics to everyday life and when trying to teach real life examples.

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However despite such obvious importance, research studies have shown evidence of inadequate knowledge of mathematics amongst teachers' (Ball, 1990; Ma, 1999). Many teachers exhibit a rule based sense of understanding of the subject and this is reflected in their teaching (Kulm, 2008). Many reasons are cited for this throughout the literature. Brown & Borko (1992) suggest that there are limitations in teachers' knowledge in mathematics when leaving training college. There needs to be a greater connection linking the content which prospective mathematics teachers learn in college and the content which they will be teaching in schools as one is often far removed from the other (Toumasis, 1992). There is also a high number of 'out of field' teachers currently teaching the subject. These teachers generally possess a teaching qualification but will have little or no training or education in the area of mathematics education. A relatively recent Irish study carried out by Ni Riordain & Hannigan (2009) found that 48% of the teachers who are teaching the subject did not have a mathematics teaching qualification. Furthermore, the lack of an effective continuous professional development (CPD) programme in Ireland means that practising teachers do not continue to update their subject knowledge (McConway, 2006).

Aim of the Study

This aim of this study is to investigate whether students' enjoyment scores in mathematics are influenced by their individual teachers and also to further explore how students define effective teaching.

Methodology

The authors decided to use a mixed method approach by combining both qualitative and quantitative methods of research. The use of multiple methods was decided upon in order to get an in-depth understanding of the research. The research started out as a follow-on study

that further analysed data collected by the authors when they designed a pedagogical framework with the aim of promoting student interest in algebra through effective teaching of the domain (Prendergast & O'Donoghue, 2014a). Based on this framework the authors developed, implemented and evaluated a teaching intervention in four second level Irish schools. In-depth detail regarding the design of the framework along with the subsequent development, implementation and evaluation of the teaching intervention is available in Prendergast & O'Donoghue (2014a). However this paper focuses entirely upon the quantitative results of the evaluation with regard to whether there are differences in the enjoyment scores of students' in different classes as a result of their individual teachers. The paper also looks to unravel the myth of effective teaching through a series of focus groups.

Research Design and Implementation

The intervention was developed as a fun, innovative resource pack for teachers to use when revising algebra and equations with 1st year (12-14 year old) students. The resource pack comprised of two Parts. Part 1 consisted of four lessons revising the Introduction to Algebra (variables, substitution, expansion of brackets) while Part 2 consisted of four lessons revising Equations. Every lesson was developed using activities and content that interlinked with the pedagogical framework and its underlying theoretical perspectives (Prendergast & O'Donoghue, 2014a). Once the development was complete, the intervention was implemented in 4 second level Irish schools between September 2009 and June 2010. The schools involved were selected using a convenience sampling method to include two co-educational, one single-sex male and one single-sex female schools. Two 1st year (12-14 year old) mixed ability mathematics groups from each of the four schools were randomly assigned as control and experimental groups and these made up a sample size of 177 students. In Part 1, the control group spent four classes revising the 'Introduction to Algebra' using the

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traditional textbook method. However the experimental group spent four classes revising using the teaching materials developed by the authors. Part 2 was based on the same strategy but on this occasion both groups revised 'Equations'. Each lesson in Part 1 and 2 was always solely delivered by the class teacher. In each of the four schools, two different teachers taught the control and experimental groups. Therefore, eight mathematics teachers took part in the study. The teachers were all fully qualified mathematics teachers. Throughout the study they followed specific procedures from a 'Teacher Guidelines' handbook that they were provided with. This was to ensure consistency in the implementation of the intervention across the four schools so the validity of the study would not be threatened.

Instrument Measuring Student Enjoyment

In order to gain a quantitative measure of student enjoyment it was decided upon the use of Aiken's (1974) Enjoyment Scale which is a subject specific mathematics scale used to measure the attitude of students. The Enjoyment Scale consists of 11 statements assessing students' attitudes to mathematics. Aiken worded approximately half of the items on each scale in the direction of a favourable attitude and the other half in the direction of an unfavourable attitude towards mathematics. Respondents were asked to indicate their level of agreement or disagreement with each item; 0 = strongly disagree, 1= disagree, 2 = undecided, 3 = agree, 5 = strongly agree. Scoring on negatively worded items was reversed (i.e. 0 = strongly agree). Thus a high score would indicate a more favourable attitude towards mathematics. The highest possible score on the Enjoyment Scale was 44. Such a quantitative measure was useful in recording any change in students' enjoyment of mathematics before, during and after the intervention. The reliability of the Enjoyment Scale was analysed using Cronbach Alpha scores and indicated very good reliability (>.89).

Focus Groups

This study also looked to unravel the myth of effective teaching through a series of focus groups. These focus groups were carried out 18 months after the original study. The authors returned to the four participating schools in October 2011 and carried out a focus group in each school. The focus groups were made up of volunteers of students from a mixture of the control and experimental groups of the previous study. 29 students took part in the focus groups in total. Each student was coded to ensure confidentially (P1-P29). Their responses were transcribed and analysed using NVivo software and arranged into themes by the authors and a mathematics education colleague.

Results of the Study

Quantitative Data

The data collected from the Enjoyment Scales consisted of responses from 177 students (87 in the control group and 90 in the experimental group). Missing data was also coded to account for any unanswered questions, cases in which two or more answers were circled or if a student was absent. The Enjoyment Scale was given to both the control and experimental groups at five different times namely:

- Baseline Enjoyment Scale - This scale took place before the intervention began. The students had just finished studying algebra but had not yet revised it.
- Post-Algebra Revision Enjoyment Scale - This scale took place after the students had revised algebra for four lessons.
- Pre-Equations Revision Enjoyment Scale - This scale took place when the students had just finished studying equations but had not yet revised it.
- Post-Equations Revision Enjoyment Scale - This scale took place after the students had revised equations for four lessons.

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- Post-Delayed Enjoyment Scale - This scale took place two months after the completion of the intervention.

This descriptive analysis outlined by Prendergast & O'Donoghue (2014a) found that there was no statistically significant difference between the mean enjoyment scores of the control and experimental groups before or after the intervention. However, the mean score of students in the experimental group increased from (M: 25.40; SD: 8.95) before the intervention to (M: 26.99; SD: 9.48) after the intervention (Prendergast & O'Donoghue, 2014a). The mean score of students in the control group remained relatively stable throughout, decreasing slightly from before the intervention (M: 26.84; SD: 8.39) to after the intervention (M: 26.48; SD: 10.10) (Prendergast & O'Donoghue, 2014a). Further analysis was also carried out exploring whether other factors may have affected the changes in student enjoyment. Such factors included the school type, group, gender, teacher and the baseline level of enjoyment of each student (i.e. each student's initial level of enjoyment). A mixed design ANCOVA was conducted with repeated measures of enjoyment over time and independent factors of school type, group, gender, teacher and a covariate of baseline enjoyment. In-depth detail regarding these results and analysis with regard to school type and gender are available in Prendergast & O'Donoghue (2014b). However, this paper specifically focuses on whether the individual teacher of each class influenced student enjoyment levels. The further analysis of the data showed that there was a statistically significant effect for teacher ($p<.001$).

Qualitative Data

The evaluation of the Enjoyment Scale data shows that there was a statistically significant effect for teacher. In essence, this means that the enjoyment levels of students in different classes were affected by their individual teachers. All of the teachers who took part in the study were fully qualified mathematics teachers. Despite this, the results suggest that differing levels of effectiveness may have existed between them. There are many possible reasons for such differences, for example the beliefs, attitudes and expectations of each individual teacher as evidenced by Tiedemann (2000). Other reasons may include differing teaching styles, the number of years' experience, level of education or institution of study. A limitation of this research is that such information was not obtained from each participating teacher so that these issues could not be examined in more detail. However, the statistically significant teacher effect undoubtedly highlights the important role which teachers play in shaping the attitudes of their students in the mathematics classroom. The authors aimed to use the focus groups to investigate what students definition of an effective teacher of mathematics is.

The majority of student responses when asked for a definition of effective teaching centred on the teacher caring for students.

> P12: *I think that an effective teacher is someone who cares for their students. They are not just basically doing their job for the sake of doing it. They really want their students to achieve and will do everything they can to help them.*
>
> P15: *I like teachers who care about all their students, not just the really good ones. They understand that some of us are not good at maths but have different talents.*
>
> P28: *the good teachers care about what happening in our lives outside of school. Its not just a 9 – 5 job for them. They are someone I could trust if I was in trouble.*

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Similar to the study carried out by Smyth et al., students felt that effective teachers are good at explaining things (P4: "an effective teacher makes things easy. They can explain things in a way that we understand") and have the patience to explain things in a number of ways (P2: "They have a few different ways to explain things. If we don't get it the first way they will try another until we do get it. That takes a lot of patience").

Effective teachers are enthusiastic and enjoy their job.

> P20: *they love and are really interested in their subject. It's easy for me to see what teachers have a passion for their subjects and what teachers don't*).
>
> P11: *their enthusiasm for the maths rubs off us in the end.*

This makes the topic fun and interesting (P17: "They are fun and make the subject fun").

Effective teachers also use a variety of teaching methods and relate the topic to everyday lives.

> P8: *They like to try different things in class. Its not always just the same lesson. We sit there and listen while they talk or we take notes while they write on the board. They do different stuff like quizzes, group work, show video clips. Just makes it a bit more interesting.*
>
> P18: *They don't just follow the textbook. We are always doing different things in class which help us understand better.*
>
> P1: *They always try and relate the maths to our lives, to make it interesting and relevant.*

The teacher's subject knowledge is important.

> P12: *an effective teacher, knows their stuff. They know everything about maths and want to share it with us'*. P3: *'they always look for other ways of doing things. They love when one of us comes up with an alternative method. Our teacher always says that maths is about the method not the answer.*

An effective teacher must be able to control a classroom (P10: "They have good control of the classroom. But they don't have to shout at us. They just have our respect. I think that comes from us knowing that they want us to do well. They're not on a power trip").

Students mentioned the importance of teacher's personal attributes and their attitudes and expectations.

> P11: *Some people are just born to be teachers while others are not. Some people want to help students while others just like the power.*
>
> P2: *good teachers are kind and approachable.*
>
> P9: *an effective teacher believes in us. They don't judge us or have expectations based on who our sister or brother is or who our parents are. They treat us all equally*.
>
> P28: *they have high but realistic expectations of us. They may know that we might not become rocket scientists but still want us to achieve to our full potential.*

Finally an effective teacher will work hard and will always be fully prepared.

> P22: *the really good teachers are always really well prepared. They have everything thought out at the start of the year, like when they are doing certain topics and when assessments are. Every class they have good notes for us and resources ready. It's obvious that they care.*

Discussion and Recommendations

The findings from the focus groups conform to the findings of the literature. Effective teaching must focus on individual teacher attributes such as attitudes and expectations along with developing progressive teaching styles and an in-depth subject knowledge base. Each of these has been discussed and analysed comprehensively in the review of literature. In short, the first step in the pursuit of effective teaching may lie in attracting candidates of the right personality traits, calibre, orientation and emotional intelligence to the profession (Salami, 2007). After all, effective teaching comes from the identity and integrity of the teacher (Palmer, 1998). Once recruited, these candidates must be helped to further develop such

positive attributes along with their teaching styles and knowledge base. Teacher training and continued professional development (CPD) have an important role here. Adequately trained and fully supported teachers in schools are an absolute necessity of education (Smith, 2004). As established in the literature review, teachers must have a rich and flexible knowledge of the subjects they teach. They must understand the central facts and concepts of the discipline, how these theories are connected and the process used to establish new knowledge (Ball, 1990). This is certainly not an easy endeavour and can pose problems for new or 'out of field' teachers whose knowledge is limited. This is where the importance of CPD comes to the fore. However, its provision is also important for experienced teachers. It is essential they are given the opportunity to refresh their skills and to renew their enthusiasm for the subject. They must also be kept up to date in new content and curricular changes such as those proposed by 'Project Maths'. Advances in technology have also impacted both on the subject matter and on possible modes of teaching and learning. Every day teachers are met with new challenges in their classrooms. Hence, high quality, effective CDP is essential to effective teaching (Smith, 2004).

Similar to other professions, more must also be done to evaluate a teacher's performance. This could help to identify ineffective teachers who should be prioritised in undergoing intensive retraining and CPD. To date very little has been published that relates directly to quantifying teacher effectiveness (Markley, 2004). Davey (1991) explained that evaluating teachers is difficult as there is no end product to assess. However multiple methods such as teacher portfolios and peer evaluations have evolved and further research and work in this area is needed.

Conclusion

The evaluation of the Enjoyment Scale data shows that there was a statistically significant effect for the teacher in the enjoyment scores of their students. This, along with support from the focus groups and the literature, highlights the importance of effective teaching. Although this study focused on second level teachers, the same recommendations can apply to teachers at all levels, particularly at third level. While the majority of lecturers at third level are experts in their subject field, this is only one aspect of effective teaching. Many may not have considered some of the pedagogical implications of teaching such as alternative teaching styles and methods, ongoing CPD and linking their subject matter to other modules and everyday life. It is clear that effective teaching at all levels is an important but complex and intricate endeavour. The findings of the focus groups confirm that no matter how one defines effectiveness, there is an understanding that teaching "involves a complex set of knowledge, abilities, and personal attributes in dynamic interplay" (Davey, 1991, p.121). In the words of William Glasser (b.1925) it may well be "the hardest job there is".

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