

Motivating young people to seek careers in STEM: Research conclusions from interviews and observations in Ireland and the U.K.

Jim Freemyer^a, Patrick Johnson^b and Olivia Fitzmaurice^b
Indiana Wesleyan University^a; University of Limerick^b

The purpose of this research was to determine if Irish and U.K. mathematics teachers would support or deny what Indiana mathematics teachers would say are the most important skills necessary to successfully engage second-level students in maths. These European teachers would assess effective teaching strategies initially identified by some of Indiana's most effective maths teachers, providing a multi-national perspective on effective teaching practices. It is hoped that this research would allow Irish, U.K. and U.S. maths teachers to learn from each other. Principals in these countries could then use the results to help all mathematics teachers improve and excel.

Keywords: mixed method research; effective mathematics teaching; faculty development; continuous growth

Introduction

Motivating young people to choose careers in mathematics related areas has proven a formidable task for teachers in the U.K., the U.S. and Ireland (Boaler, 2009, O'Donoghue & Hourigan, 2007). In the U.S., politicians are proposing numerous ideas to address this issue with few ideas gaining real traction. This research was an effort to search for solutions by beginning with the segment of society which is best prepared to offer viable solutions: each country's experienced mathematics teachers.

Purpose of the study

This study sought to begin a dialogue regarding improved mathematics teaching by going directly to experienced teachers in the field. Teachers (n=60) in Indiana who demonstrated success in motivating young people to score well on the American College Teaching (ACT) were asked how to best improve mathematics teaching for students ages 15- 18. A total of 60 experienced teachers in Ireland and the U.K. also were asked what is most important in motivating young people to continue their study of STEM related areas. Those teachers were observed and later asked to rate the themes identified by the Indiana teachers.

Theoretical framework

This study was informed by the Five Core Propositions adopted by the National Board for Professional Teaching Standards (NBPTS, 1989) in the U.S. Proposition Number One states that teachers are committed to students and their learning. This proposition calls for teachers to adjust their practices based on observation and knowledge of students' interests, abilities, skills, family circumstances, and peer relationships. Proposition Two challenges teachers to know the subject they teach and how to teach it to students. Proposition Three notes that teachers are responsible for managing and monitoring student learning. Included in this proposition is the

challenge that teachers know how to engage groups of students to ensure a disciplined learning environment. Classroom management and discipline are indeed key components to effective instruction that continue to baffle many mathematics teachers. Proposition Four includes the admonition to learn from experience. Proposition Five states that teachers are members of learning communities (NBPTS, 1989). Good teachers find effective ways to continue to learn.

Review of literature

This research identified three major themes of effective instruction which include the importance of (a) high expectations, (b) support and genuine concern for students, and (c) learning and growing. Those themes align well with the NBPTS Standards. Proposition One relates directly to support and genuine concern for students. Proposition Five aligns directly with being members of a learning community. However, high expectations are only implicitly implied by these standards. O'Donoghue and Hourigan's (2007) research documents the importance of improving the level of mathematical understanding for students entering the university setting and consequently providing higher expectations for second-level students.

Dr. Anne Brosnan, the National Coordinator for Project Maths in Ireland, believes student engagement is critical to the movement in Ireland (personal communication, November 25, 2014). She emphasized that using a problem-solving and enquiry approach is important for effective delivery of the syllabus. She believes the application of mathematics concepts as well as procedural knowledge are appropriate approaches to effective mathematics instruction. She advocated for increased metacognition which requires planning, problem-solving, evaluation, and discovering alternative ways of solving the same problem. These concepts align with the Indiana research results that called for high expectations for all students.

Marzano's (2011) research, summarized in his article on teaching, also emphasized the importance of high expectations that engage students in the learning process and teachers consistently assessing students throughout the learning process. Felder and Brent (2012) advocated for what they call active learning to obtain full student involvement, expand the number of responses to questions raised in the classroom and involve real-life problem solving.

Research methods

A mixed method approach was used to conduct this research. This research began by using the Delphi Method (Powell, 2003) to solicit ideas from 30 identified effective mathematics teachers in Indiana, asking them to describe effective teaching practices. Another 33 identified Indiana teachers then were asked to confirm or deny those identified practices. The Delphi approach began with a qualitative approach using an open-ended question about what constitutes effective instruction. The results led to a quantitative approach, with teachers completing a survey to confirm or deny the principles mentioned by the first half of the teachers. The survey questions used with teachers in Ireland and the U.K. were derived from those of the 60 teachers in Indiana. Irish and U.K. teachers were interviewed and initially asked an open ended question about what constitutes effective instruction for mathematics education. A majority of teachers mentioned the three themes in those interviews. When asked if they personally agree with the overall themes, 98% of interviewed teachers agreed with the principles generated by the Indiana teachers.

A second component of the research in Ireland involved a written survey to determine if the Irish teachers agreed with the principles identified by the Indiana teachers. Irish mathematics teachers were asked to rate these teaching approaches acknowledged by the Indiana teachers. A total of 142 Irish teachers completed a short survey with elements initially generated by teachers in the US. Irish teachers provided considerable feedback on the topic of what constitutes effective mathematics teaching, providing a framework for teacher development and continuous growth.

Research results

Table 1: Analysis of the component parts for challenging students to high expectations while holding them accountable

Ranking	Component of High Expectations	U.S.A. n = 33	Ireland n = 142	
		Mean out of 7	Ranking	Mean out of 7
1	Provide clear and high expectations	6.94	5	6.58
2	Challenge students to perform at a high level (effort, perseverance, and rigor)	6.91	1	6.71
3	Assess learning throughout the lesson	6.67	6	6.49
4	Hold students accountable (in-class engagement, homework, etc.)	6.64	3	6.63
5	Establish a structured climate that fosters cooperation.	6.58	7	6.49
6	Ask higher level questions frequently.	6.45	8	6.30
7	Focus on being well-organized and prepared.	6.40	2	6.68
8	Assign daily homework for practice and reinforcement.	5.94	4	6.67
9	Engage students in project-based real-life application.	5.48	9	5.92

A 7 point Scale with 7 = extremely important, 6 = fairly important, 5 = somewhat important, 4 = nice but not necessary, 3 = somewhat counter-productive, 2 = fairly counter-productive, and 1 = totally counter-productive

Challenging students to perform at high levels was identified as important to teachers in both Ireland and the U.S. Irish teachers placed more emphasis on being well-organized and the assigning of daily homework. Holding students accountable was important for both teacher groups. Assessment throughout the lesson was rated higher by U.S. teachers. Both teacher groups rated asking higher level questions and engaging students in project-based, real-life applications as important, but not as important as the other components. On a scale of 100 – 1 the Irish teachers rated the importance of high expectations 88/100, indicating the value of teachers focusing on the nine components of teaching identified in the above table. The U.S. teachers rated the high expectations category at 93/100, affirming the importance of these practices.

Table 2: Analysis of the component parts for teachers must demonstrate support and genuine care for students helping them learn

Ranking	Support and Genuine Care	U.S.A. n = 33	Ireland n = 142	
		Mean out of 7	Ranking	Mean out of 7
1	Demonstrate an enjoyment and enthusiasm for teaching.	6.72	1.	6.82
2	Demonstrate care (encouragement and support) for students through relationships.	6.59	3.	6.53

3	Encourage direct questioning and classroom discussion.	6.47	4.	6.40
4	Communicate the teacher's thought process when discussing new concepts.	6.44	9.	6.07
5	Consolidate knowledge (ideas get connected and integrated).	6.38	2.	6.57
6	Provide extra assistance outside normal class time.	6.34	15.	5.29
7	Re-cycle (spiral review) key learning concepts for student reinforcement.	6.28	6.	6.37
8	Provide students with sufficient drill and practice.	6.28	8.	6.24
9	Display a sense of humor and a lively personality.	6.25	12.	5.79
10	Plan instruction to utilize the concept that success breeds success (success seems feasible).	6.25	11.	5.90
11	Allow ample wait-time when asking challenging questions.	6.22	7.	6.28
12	Develop a culture of school pride.	5.87	10.	5.92
13	Design effective group work.	5.84	13.	5.46
14	Integrate standardized test questions	5.69	5.	6.40
15	Provide ways (mnemonics, songs, object lessons, etc.) to help students learn and remember.	5.47	14.	5.38

A 7 point Scale with 7 = extremely important, 6 = fairly important, 5 = somewhat important, 4 = nice but not necessary, 3 = somewhat counter-productive, 2 = fairly counter-productive, and 1 = totally counter-productive

The feedback from Irish teachers was very similar to the feedback from U.S. maths teachers regarding the need for continuance growth. The component parts included (a) Keep learning new teaching strategies, (b) Continue to grow regarding understanding of their content area, (c) Participate in teacher collaboration, (d) Implement effective instructor use of technology to enhance student engagement, and (e) Implement effective student use of technology to enhance understanding.

Irish and U.S. mathematics teachers were in general agreement regarding the importance of seeking ways to continually grow in relation to their practice. Irish teachers placed more focus on growth related to their content knowledge. U.S. teachers rated the overall category of Continuous Growth at 86/100 and the Irish rated it at 80/100.

Observations and interviews of 60 Irish and UK teachers

In the autumn of 2014, 15 mathematics teachers from Ireland consented to being observed while teaching and later the same day be interviewed to discuss effective mathematics instruction. Most of these teachers were identified as highly effective mathematics teachers by university professors at the University of Limerick. Five teachers from a more disadvantaged school were also interviewed and observed. A total of 45 teachers from the U.K. were observed and interviewed in December, 2014. Letters were randomly sent to numerous schools throughout the U.K. with those agreeing to participate in the study constituting some of the United Kingdom's better performing schools according to the self-report of department chairs. One average performing U.K. school also was chosen for the study. All interviews began with an open-ended question seeking teacher comments on what they considered to be best practices in effective mathematics instruction. Teachers then were asked to comment on the three main themes generated by the Indiana study.

Teachers noted in the open-ended questions that (a) a teacher must really like mathematics, have a real love and passion for mathematics, (b) have a well-disciplined and structured classroom, (c) have high expectations for yourself and students, (d) care and demonstrate concern for students while demonstrating relationships, and (e) keep students engaged. While 98% of the teachers interviewed affirmed all three of the main themes of the research, only 20% noted continued growth when asked what good teaching really was in a totally open-ended question.

When asked what constitutes the other 12% of teachers reiterated the importance of love and passion for mathematics. Other components of effective teaching that were identified in the last question of the interview of teachers included (a) utilizing technology, (b) teachers being firm but pleasant in a structured environment, (c) utilizing group work, (d) knowing the content, (e) keeping students engaged throughout the lesson, and (f) assessing throughout the lesson.

Teacher observations were conducted of the 60 Irish and U.K. teachers. An observation framework, developed by Dr. Tim Rowland and adjusted by Liston (2013) was used for teacher observations. The Knowledge Quartet for second-level live teaching was determined to be appropriate for the framework (M. Rowland, personal communication, November 8, 2014). The adjusted framework included four main components: (a) foundation, (b) transformation, (c) connection, and (d) contingency. Observation comparisons of Irish teachers and UK. teachers found that 83% of Irish teachers demonstrated real-life examples and 55% from the U.K. Teaching with conceptual examples was exactly the same for observations in both countries at 66%. Teachers in the U.K. scored at 28% on contingent thinking compared to 17% in Ireland.

Research limitations

The research began with the Delphi Method (Powell, 2003) being used to justify key teaching components by some of Indiana's most effective mathematics teachers. Those identified principles were then used to generate a survey for Irish teachers to confirm or deny. The cultural differences were addressed by having Irish professors edit the survey and rephrase appropriate wording to align with Irish educational vocabulary. The research approach utilized both a qualitative and quantitative approach, providing meaningful data for analysis.

The survey was completed by 142 Irish mathematics teachers which represents slightly less than 20% of teachers who are members of the Irish Mathematics Teachers Association. Irish teachers confirmed the importance of the 28 subcomponents of the three main themes but the survey ratings were personal perceptions and not detailed analyses of what the mathematics teachers really believe as demonstrated by utilizing the principles in daily practice. The observations and interviews of the 60 teachers in Ireland and the U.K. might not represent what occurs daily in the classroom. A guest observing can impact normal practices.

Significance of the study

The research confirmed that effective mathematics instruction which motivates young people to consider careers in the STEM arena requires teachers to demonstrate enthusiasm and excitement about the subject area. Teachers must have high expectations and hold students accountable to those expectations. Teachers must find ways to partner with students to help them succeed and teachers must work with colleagues to improve their teaching approaches.

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