The Modelling Process and Pre-Service Teacher Confidence

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Many teachers and pre-service teachers of mathematics lack experience with teaching methods, such as mathematical modelling, that require a conceptual learning and problem solving approach. To address this problem, this paper presents a study of a method – the Enhancement, Learning, Reflection (ELR) process – that has been designed to improve pre-service students' confidence in teaching mathematics, with a particular focus on the use of modelling as a teaching method. Results from the case study show that the PST participants involved in the ELR process did indeed experience an increase in confidence in their ability to present the modelling concept to a classroom of high school students.

Teachers' confidence in their own mathematical abilities – or lack of it – can have a powerful effect on their students (Laursen, Hassi, & Hough, 2016). For pre-service teachers (PSTs), confidence is strongly shaped by their own learning experiences in the mathematics field. This means for many PSTs, because past teaching methods may have emphasised procedural skills over conceptual learning and problem solving, teaching situations that require a more laissez-faire approach often lead to increased anxiety and therefore a lack of confidence (Laursen et al., 2016; Shilling, 2010).

Indeed, despite the increasing number of suggested methods for addressing the adequate training of PSTs, a lack of confidence amongst teachers of mathematics and the adverse effects this has on student learning and engagement remains a problem in Australia (Hamlett, 2009; Victorian Auditor-General, 2012; Yeigh et al., 2016). To foster the development of greater confidence in the area of mathematics education, PSTs arguably need to be offered the chance to engage in deeper, more reflective learning opportunities that also encourage self-reflection, novel ways of thinking and the utilisation of new or unfamiliar teaching methods. One approach that offers these learning opportunities is inquiry-based-learning (McGregor, 2016; Yoshinobu & Jones, 2013). In contrast to more traditional lecture-as-instruction methods, an inquiry-based-learning classroom passes mathematical authority to the student (Trigwell, 2012). This means the role of the inquiry-based-learning educator thus changes from a prescriptive "information giver" to a facilitator who poses questions and guides students' construction of ideas.

One field of mathematics that reflects those tenets of inquiry-based-learning, but which is often categorised under different name, is modelling. Mathematical modelling can be defined as a "process of representing real-world problems in mathematical terms in an attempt to understand and find solutions to the problems" (Ang, 2010, p. 53). Consistent with the inquiry-based-learning approach, as a learning process modelling intends to present students with novel data and requires the learner to explore relationships within that data (McGregor, 2016). Modelling also helps learners (both students and PSTs) to both express and adapt their current ways of thinking in order to read, interpret, and then develop useful tools/models for solving specific problems. It can also help to awaken

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critical and creative senses which can thus provide the leaner with better comprehension of mathematical concepts (Atlay, Ozdemir, & Akar, 2014; Biembengut & Hein, 2013).

From a teaching perspective, various studies have shown that many teachers have difficulties in understanding modelling and therefore avoid using modelling problems in their classrooms (Atlay et al., 2014; Pereira de Oliveira & Barbosa, 2013; Thomas & Hart, 2013). This is largely due to lack of experience and knowledge related to the pedagogical issues such as how to manage the process (Biembengut & Hein, 2013; Borromeo Ferri & Blum, 2013; Ng, 2013), as well as the reality that when teaching modelling, the teaching process becomes more open and less predictable (Blum & Borromeo Ferri, 2009; Thomas & Hart, 2013) therefore requiring teachers to have confidence in their mathematical abilities (Atlay et al., 2014). Blum (2015) suggests that one way of providing future teachers with the necessary professional knowledge is to offer specific modelling courses which also include compulsory own teaching experiences as a required component of their education degree.

In current teacher education courses, the specific development of modelling skills are often either missing or only briefly touched upon in the mathematics education components (Biembengut & Hein, 2013; Pereira de Oliveira & Barbosa, 2013; Villarreal, Esteley, & Smith, 2015), yet modelling can serve many functions consistent with an inquiry-based-learning approach. This paper presents a case study where modelling is used as a method to develop PSTs' confidence in teaching mathematics, and proposes that such skills be a core component of the preparation of mathematics teachers.

Method

To improve the training of teachers at the university level by addressing the lack of confidence in science and mathematics instruction among teachers in secondary Australian schools, six universities across Australia have been participating in an Office of Learning and Teaching project: *It's Part of my Life: Engaging University and Community to Enhance Science and Mathematics Education*. An outcome of the project is a new university teaching method, the Enhancement-Lesson-Reflection process (ELR), which has been designed specifically to address PST confidence. By utilising conceptual learning and problem solving methods, the ELR process teaches PSTs how to take a student-focused learning approach. The process involves engaging PSTs in multiple, repeated sessions that focus on learning and planning (enhancement), teaching (lesson), and feedback and reflection (reflection). This paper reports only on the research completed at the University of Southern Queensland (USQ) where modelling was used as the teaching method.

Participants and the Enhancement-Lesson-Reflection (ELR) Process

Nine PSTs participated in 2015 USQ *It's Part of my Life* program. The PST participants were 2nd-, 3rd-, and 4th-year students studying to become middle- or high-school mathematics teachers at either the Toowoomba (five PSTs) or the Springfield (four PSTs) campuses. Four of the PSTs were males and five were females.

Engagement in the USQ *It's Part of my Life* program required the participants to attend a number of ELR sessions across the teaching semester. All participants were required to attend the introductory enhancement session at the beginning of the program and the group feedback session at the conclusion of the program. In the introductory session, the PSTs were taught about the concepts and theories behind mathematical modelling and were then presented with a mathematical modelling problem to which they had to develop a solution.

In this regard, they were experiencing the mathematical modelling process from the perspective of a student. This introductory session was presented by a visiting educational expert whose area of expertise was the teaching of mathematical modelling. The group feedback session held at the end of the semester required the students, as a group, to reflect on the ELR process and its impact on their teaching and learning experiences. Throughout the program, each participant was also required to: attend an enhancement session with an expert mentor(s) to plan their lesson, teach one session, and engage in a reflection session follow up with their expert mentor(s) the week following their teaching experience. They were also asked to observe and engage in the feedback/reflection sessions for at least three of the other lessons taught by their peers. There were six sessions in Toowoomba and five sessions in Springfield.

The students to whom the Teaching PSTs presented their lessons were Year 9 and 10 students from local high schools attending on-campus sessions. A total of 25-40 students participated in each session. The teaching sessions lasted two hours and were divided into three segments. The first 15 minutes were used as an introduction and time for the students to meet the teaching team over refreshments. Over the next 90 minutes, the students were presented with a real-world problem which they then, in small groups, worked to: devise a group-generated formulation to the presented problem; discuss assumptions and variables; develop a mathematical solution; model possible solutions; and interpret the real world meaning with further model refinement (Stillman, Galbraith, Brown, & Edwards, 2007). The final 15 minutes included a conclusion and collection of survey data. The role of the Teaching PSTs was to lead the main 90-minute segment of the lesson. With the assistance of an expert mentor (a university mathematics lecturer, a practicing mathematician, or a combination of the two), the Teaching PST presented the students with a real-world problem and then guided them through the modelling process.

Data Sources and Analysis

Following a mixed-method approach, a combination of a qualitative and quantitative data collection method was utilised. The quantitative method was used to investigate self-reported changes in PST confidence using a pre- and post-experience survey, and the qualitative interview method was used to further probe by interview how the participants perceived their confidence had changed following their classroom teaching experience.

Confidence and Competence Checklist (CCC) Survey

The CCC survey was specifically developed for this study to measure PST confidence. The survey was first designed to be based on the Australian Institute for Teaching and School Leadership's (AITSL) seven professional standards for the domains of teaching. Piloting of the survey led to its refinement to become more focused on personal aspects of confidence in the teaching situation. The refined CCC survey includes eighteen questions and asks respondents to indicate, on a five-point Likert scale, how confident they felt about teaching with regards to five aspects of the teaching experience: lesson planning, classroom presentation, ability to centre the lesson on student needs, lesson management, and ability to self-evaluate.

To determine whether the ELR process was effective in changing the participating PSTs' perceived confidence, the CCC survey was completed before and after the PSTs performed their allocated teaching task. Data from the CCC pre- and post-surveys were combined into five confidence factors to reflect the five aspects of the teaching experience

on which the respondents were asked to reflect. Using a Wilcoxon matched-pairs signed-rank test, each of these factors was analysed to assess for changes in confidence using the research question: Did students become more confident after the ELR process in teaching mathematics? The Wilcoxon matched-pairs signed-rank test is a non-parametric, statistical hypothesis test used when comparing two matched samples or repeated measurements on a single sample to assess whether their population mean ranks differ (McDonald, 2014).

Post-Teaching Session Recorded Debrief

At the conclusion of each teaching session, the Teaching PST was asked to reflect on their experience in an audio-recorded debrief. During this debrief the PSTs were asked to reflect on: how the enhancement sessions contributed to their confidence in the lesson they taught, how feedback from prior sessions influenced their confidence, and how the lesson itself may have impacted on their confidence. These semi-structured interviews were completed directly after the Teaching PST's teaching session to enhance the ability to capture participants' immediate feelings about their performance. For each campus, the person conducting the interviews was the main academic responsible for the study on that campus. Using a grounded theory approach (Glaser & Strauss, 1967), the interview recordings were analysed using both manifest and latent content analysis techniques. This meant the data were analysed for both the appearance of a particular word or content (Potter & Levine-Donnerstein, 1999), as well as for the meanings implied through the communications (Holsti, 1969). The aim of the analysis was to further assess whether PST confidence changed or improved as a consequence of the ELR process.

Results and Discussion

Confidence and Competence Checklist (CCC) Survey

The five pre-defined factors designed to assess PSTs' feeling of confidence in their teaching ability were tested for reliability using Cronbach alpha to ensure all factors had a reliability value of approximately 0.7 or higher (see Table 1). The factor "ability to self-evaluate" was omitted because in the post CCC survey, five students stated that they were not able to rate this factor.

The Wilcoxon matched-pairs signed-rank test was used to test for changes in confidence. It assessed how confident the PSTs felt at the beginning of the ELR process compared to how confident they felt following their classroom teaching experience. The results of the Wilcoxon matched-pairs signed-rank test shows that for the factor "presentation skills", PSTs experienced a highly significant increase in confidence. For the factors "student learning" and "effective planning", there is moderate evidence to suggest an increase in confidence, while for the factor "lesson management", there is no evidence to support an increase in confidence.

To test for an increase in overall confidence, the mean and standard deviation for each of the four factors being examined were calculated (see Table 2). A higher mean ranking emerged for all four factors for the post CCC survey in comparison to the pre CCC survey, indicating a general increase in PSTs' confidence after they had undertaken the teaching task. A Wilcoxon matched-pairs signed-rank test further confirmed this overall increase in confidence ($Z = 2.194$, $p = 0.014$, one-tailed).

Table 1
Results of the Cronbach Alpha and Wilcoxon Matched-Pairs Signed-Rank Test for the Four Factors Examined

Survey Factor	Cronbach alpha	Test Statistic	*p*-value
Effective planning	0.694	Z = 1.897	0.029*
Presentation skills	0.825	Z = 2.224	0.0075**
Student learning	0.967	Z =1.703	0.0445*
Lesson management	0.953	Z = 1.160	0.123

* Significant at the 5% level. ** Highly significant

Table 2
CCC Pre- and Post-Survey Factors

Survey Factor	*N*	Minimum	Maximum	Mean	Std. Deviation
Effective planning (pre)	9	3.40	5.00	4.0000	0.47958
Effective planning (post)	9	4.00	5.00	4.3778	0.36667
Presentation skills (pre)	9	2.75	4.50	3.5833	0.55902
Presentation skills (post)	9	4.00	4.50	4.2222	0.23199
Student learning (pre)	9	1.67	5.00	3.4815	1.04231
Student learning (post)	9	3.00	5.00	4.1111	0.60093
Lesson management (pre)	9	2.00	5.00	3.5926	0.92463
Lesson management (post)	9	3.00	4.33	3.9259	0.40062

From the perspective of the ability for the ELR process to increase PST confidence, the results from the CCC survey provide evidence that for the 2015 cohort engaging in the *It's Part of my Life* project, the program was successful in its aims. It also provides evidence to support the argument for the use of problem solving as an approach that may offer mathematics PSTs deeper, more effective, and more relevant learning opportunities that increase their confidence to generate, explore, and analyse unfamiliar ideas.

Post-Teaching Session Debrief

When asked to reflect on how the enhancement sessions and/or how previous feedback had contributed to how confident they felt when teaching their classroom lesson, all but two of PSTs responded positively. The general consensus was that both the enhancement sessions and the individual feedback were important for helping the PSTs to identify those elements specific to their own teaching practices that they may have needed to focus on or improve due to confidence reasons. One participant, for example, identified the need to improve her confidence in speaking to a group, and from the enhancement sessions felt more ready to deliver her teaching session:

> I have learned a lot from it (the enhancement session). The hard part for me is the practice of talking and it has shown me how when I deliver my lesson I (need to) try to make my voice louder.

Another participant admitted that while the enhancement session made her more nervous, it also made her feel more confident as it made her think about things she had not previously thought about with regards to teaching her lesson. Another concurred, explaining that the enhancement session made her realise that she needed to make sure she was fully prepared for her classroom experience and this included all the small touches, such as making sure their spelling was correct in classroom handouts and PowerPoint slides. In this participant's words:

> The enhancement sessions contributed a lot to my confidence. If I had to do it (the teaching session) without that assistance I would have been lost.

Three of the PSTs mentioned that an important lesson that came from the enhancement sessions, and which subsequently contributed to increasing their feelings of preparedness for the classroom teaching experience, was the realisation that in teaching mathematical modelling flexibility was a key teaching quality. This is because mathematical models often have multiple ways of approaching the problem and success comes from being able to manage unknowns as they arise. As explained by the respondents:

> With building my confidence I could see [from the enhancement sessions] that unforeseeable problems are inevitable and that you can still basically have a successful session. I had been pretty nervous dealing with the unknowns but coming in today [for the teaching session] on the back of the other sessions, it wasn't that difficult.
>
> It [the enhancement sessions] helped me to understand that in maths modelling you don't need an exact answer.
>
> The enhancement sessions were really important for my confidence and broadening my ideas. I learnt it is [more] about extending the kids and that helped guide me.

With regards to how the actual classroom experience impacted on perceived confidence, all but one PST expressed feeling more positive as the lesson progressed. As explained by one respondent:

> When the students got really involved I settled down and my enthusiasm increased as I fed off their enthusiasm.

Four of the students mentioned feeling more confident in their own mathematical and modelling abilities as a consequence of undertaking the ELR process. Here, statements related to ability were important indicators for the perceived confidence of the respondents:

> The enhancement process improved my confidence in how to do maths modelling. And it improved my confidence in being able to do this again in the future.
>
> The feedback helped my confidence because if I know what I can improve on from positive and negative feedback, then I can work to improve [on those things].
>
> By constantly updating my [chosen classroom] problem by going through the modelling process, the modelling process really helped me with planning the lesson. In the end, I thought it worked really well and I was very happy with end result.
>
> The process taught me a lot about trying to get the kids more engaged. It helped me to focus on the maths side of things rather than focussing [too much] on the modelling process. It taught me to try to get the kids engaged without giving them too much. It taught me to make it [the problem] real life with lots of variables and to facilitate rather than telling them [the students] how to do it. It really taught me to change the way I teach.

The two of the participants who felt the enhancement and feedback sessions had impacted negatively on their confidence levels described feeling overwhelmed after the enhancement sessions. This feeling then led them to doubt their confidence in being able to teach the modelling subject matter. On both occasions, however, once the student had

further discussions with a university mathematics educator about the experience, they then felt more confident again and more ready to undertake the task.

Conclusion

The ELR process has been developed through the collaborative efforts between six Australian universities to address the need to develop in PSTs an improved sense of confidence in the classroom. This paper reports the results of the USQ's 2015 iteration of the *It's Part of my Life* program, which utilised modelling as a teaching method.

This case study has provided evidence that the PST participants involved in the ELR process experienced an increase in confidence, particularly in their ability to present the modelling concept to a classroom of high school students. The results thus demonstrate the potential positive application of the ELR process as a teaching method that may be adopted by universities to address issues related to PST confidence in the classroom and personal efficacy in the realm of mathematics education.

While the results from this single case study provide only a snapshot of the potential application of the ELR process as a teacher preparation method, a broader understanding of the ELR process will be gained once these results are combined with the results that are emerging from the other universities participating in the process. Combined results from multiple iterations of the program at USQ will also produce findings that are more generalisable; however, this paper does not purport to present a fully developed university teaching method. Instead, the aim was to show how the trialled application of the ELR process at USQ has already generated some positive results.

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