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Evaluating the Professional Learning of Secondary Mathematics Teachers: Reflecting on their Reflections!

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The need to provide quality professional learning opportunities if change is to be realised in classrooms is well documented (e.g., Guskey, 2002). A new secondary mathematics syllabus in NSW was the impetus to design a course offered through the Division of Professional Learning at the University of Sydney. The course addressed key changes to the syllabus but also encouraged participants to reflect on their practice and to consider ways they might implement the recommendations. It is acknowledged that providing such opportunities does not automatically guarantee change will occur. However, supporting teacher growth through continuous contact over a six-week period where teachers are given opportunities to share understandings and develop partnerships might afford greater chances for change. The thirty participants completed weekly surveys that involved reflecting on what they had learnt, describing how they had shared new ideas with colleagues, and evaluating new information in relation to their knowledge and current needs. The results suggest that teachers valued the course, and felt they had been supported in knowledge development. However for some teachers, opportunities to reflect on their learning indicated that their levels of reflection were limited to listing strategies they might use rather than critically reflecting on their practice. Follow-up interviews with two experienced, creative teachers confirmed that they enjoyed the course, and learnt a great deal, yet they both found the reflective process to be rather confronting.

A new mathematics syllabus for students in Years 7 to 10 was implemented in New South Wales (NSW) from 2004 (Board of Studies NSW, 2002). It replaced two syllabuses, one for students in Years 7 and 8 and another for students in Years 9 and 10. The new document contained similar content but introduced a fundamentally new approach for meeting the needs of the full range of students. The earlier syllabus for students in Years 9 and 10 was structured into three courses – Advanced, Intermediate and Standard (BOSNSW, 1996). The new syllabus has one course with three identified “endpoints” (BOSNSW, 2002). However teachers are encouraged to extend students as far as possible in each of the content areas of Number, Patterns and Algebra, Data, Measurement, and Space and Geometry. Another change involved the integration of a process strand, Working Mathematically, into all five content strands. Furthermore, the use of a range of technologies is encouraged including the use of spreadsheets and dynamic geometry software, as well as graphics calculators.

While the role of the Board of Studies is to develop curriculum and support materials, it is the role of systems (public, independent and Catholic) and schools to provide support for teachers as they implement the syllabus. The Department of Education and Training in NSW (DET) organised a large number of workshops and training opportunities for teachers in the public school system. The other systems have also organised a range of professional development activities. In addition, teachers and schools are able to access support through professional associations or private providers.

At the University of Sydney, the Division of Professional Learning has been developing courses for teachers and other practitioners. One course, the *Certificate of Secondary Mathematics Education* (CSME), was designed with a particular focus on the implementation of the new mathematics syllabus. It was advertised extensively to all secondary schools in the Sydney region with the first course conducted during February and March 2005. Thirty participants completed the Certificate by attending a one-day conference followed by six consecutive Wednesday evening workshops. Participants were required to complete a “reflection on their learning” survey at the beginning and end of each workshop. In addition,

two participants were interviewed one month after the completion of the course to gather further evidence of learning. This paper reports on designing the course, evaluating the professional learning of participants from responses to surveys and interview questions, and reflecting on the teachers' reflections in order to refine the CSME and plan future learning experiences.

Designing Quality Professional Learning Opportunities

Changing Teachers' Practice in Mathematics Classrooms

Changing teachers' practice suggests there may be something wrong with what they are already doing. This is not necessarily the case since a change in the mandatory curriculum may require adjustments of programs and practices so that they align more closely with new requirements. Facilitating such change may only require training, adaptation, personal development, local reform, or systemic restructuring as described by Clarke and Hollingsworth (2002). However, if the change to the curriculum requires a fundamentally new approach to teaching and learning, then changing teachers' practice suggests providing opportunities for growth or learning over an extended period of time in a community of learners.

Planning professional learning opportunities for teachers in relation to a new curriculum, or new approaches to teaching and learning, requires consideration of several factors including teachers' knowledge, beliefs and attitudes. There is a significant body of research indicating that teacher's knowledge and beliefs about the discipline of mathematics, teaching mathematics, and learning mathematics impact on classroom practice (e.g., Wilson & Cooney, 2002). One way to approach professional learning is to encourage teachers to reflect on their experiences as learners of mathematics and to discuss their beliefs and practices as this may better prepare them to embrace new approaches, or reform recommendations (Artzt & Armour-Thomas, 2002). Rather than change in beliefs and attitudes preceding change in practice, Guskey's (1986, 2002) model of teacher change proposes professional development precedes the implementation of new ideas in classrooms, which when implemented could lead to a positive change in student learning outcomes, and subsequently, a change in teachers' beliefs and attitudes (Figure 1).

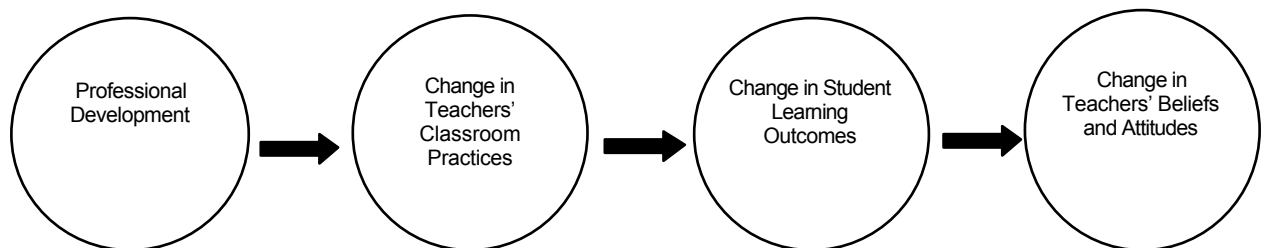


Figure 1. A model of teacher change (Guskey, 2002, p. 383)

This model suggests that teachers need to try new ideas and witness positive student outcomes before they fully embrace such approaches. Schoen, Cebulla, Finn and Fi (2003, p. 255) investigated the teacher variables that relate to student achievement when using reform curriculum materials, and found that the “completion of a professional development workshop focused on preparing to teach the course effectively” was a significant contributor to growth in student achievement. Their research supports the findings of others concerning

the need for focused professional development on the importance of the teacher’s role in promoting student understanding (e.g., Clarke, 1997).

Another model of teacher change, proposed by Clarke and Hollingsworth (2002, p. 951), is the “interconnected model of professional growth”, with four domains and two mediating processes of reflection and enactment. The four domains, which impact on the change environment include:

- the external domain – sources of information, stimulus or support;
- the personal domain – knowledge, beliefs and attitudes;
- the domain of practice – professional experimentation; and
- the domain of consequence – salient outcomes (Figure 2).

The authors recognise that the four domains are “analogous (but not identical) to the four domains identified by Guskey (1986)” (p. 950). In describing the process of change, Clarke and Hollingsworth (2002, p. 951) state:

Change in one domain is translated into change in another through the mediating processes of “reflection” and “enaction”. The term “enaction” was chosen to distinguish the translation of a belief or a pedagogical model into action from simply “acting”, on the grounds that acting occurs in the domain of practice, and each action represents the enactment of something a teacher knows, believes or has experienced.

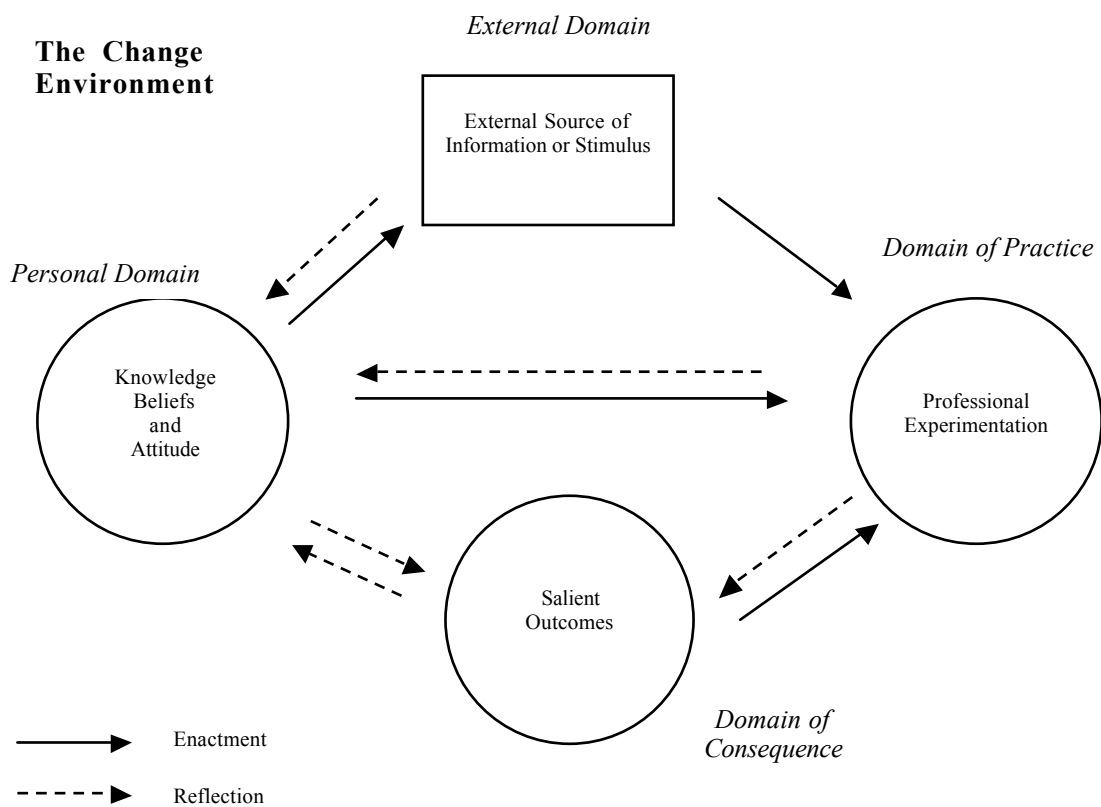


Figure 2. The interconnected model of professional growth (Clarke & Hollingsworth, 2002, p. 951)

According to Clarke and Hollingsworth (2002), the model has three functions, which may be useful when planning, evaluating, or analysing the outcomes of professional learning opportunities – as an analytical tool, a predictive tool, and as an interrogatory tool. However,

in their study, Clarke & Hollingsworth (2002) used the model to identify patterns of growth, specifically “change sequences” which consisted of changes in two or more domains with associated links, as well as “growth networks” which involved more lasting change. Critical to the model is the change environment since some school contexts support teacher professional growth while others may not. In her longitudinal study of teacher change, Hollingsworth (1999) explored the professional growth of six primary school teachers over an 18-month period. The Exploring Mathematics in Classrooms (EMIC) professional development program involved teachers meeting on a regular basis to investigate a range of teaching strategies, which they then implemented in classrooms. She was able to identify elements, which supported change including appropriate resources and equipment, supportive staff, and a professional development culture in the school.

A different interconnected model of teacher change is proposed by Weissglass (1994) who cautions “personal transformation leading to changed pedagogy often entails emotional struggle. It does not simply happen from a desire or a request to change” (p. 69). This model of change considers teachers’ emotions including their feelings and beliefs (Figure 3). It is based on the assumption that

... educational change requires personal transformation and improved collegial relationships. It has four components, viewed as the vertices of a tetrahedron. This model implies that no one component is more important than any other and that each component is essential to the change process (p. 69).

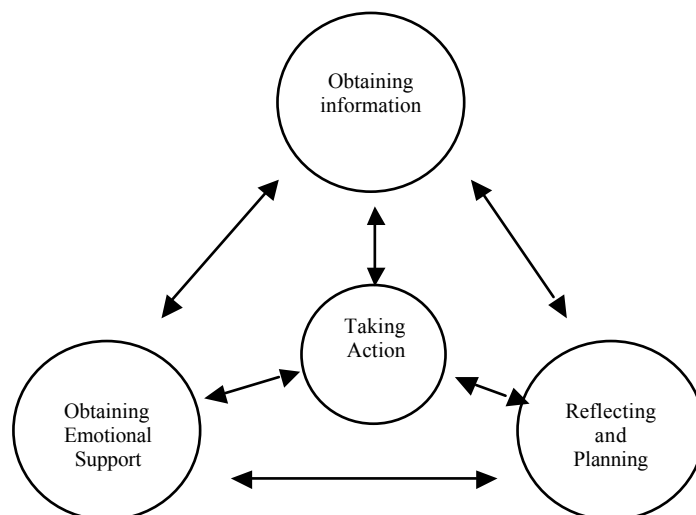


Figure 3. A model for addressing teachers’ feelings and beliefs (Weissglass, 1994, p. 70)

One way of obtaining emotional support is to provide opportunities for teachers to work together, sharing their experiences, discussing issues associated with the implementation of new approaches, and planning to use new teaching ideas. Wenger (1998) describes a community of practice where teachers learn through mutual engagement and joint enterprise, and develop a sense of belonging to the group. The benefits of studying within a community of learners, is widely documented (Clarke & Hollingsworth, 2002; Ewing, 2002; Zeichner, 2003). As Joyce and Showers (1995, p. 6) state:

Without companionship, help in reflecting on practice, and instruction on fresh teaching strategies, most people can make very few changes in their behaviour, however well intentioned they are.

The role of reflection on practice is critical in the learning process as well as in changing what occurs in classrooms (Artzt & Armour-Thomas, 2002; Clarke & Hollingsworth, 2002;

Weissglass, 1994). Recognising the teacher as a reflective practitioner acknowledges the experience and expertise that teachers bring to any professional learning opportunity, and recognises that teachers continue to learn about teaching throughout their careers. Providing opportunities for teachers to reflect on their practice and experiences can take several forms, including surveys, reflective journals, discussions between groups of teachers in focus group meetings, and interviews. Lopez-Real (2003) argues that the use of reflective journals can be an isolated and introspective activity and so he recommends sharing between individuals or groups to encourage teachers to become more critical and analytical. In the studies described by Clarke and Hollingsworth (2002), interviews and videotapes of lessons were used to illicit reflective comments about change in practice, as well as beliefs and attitudes. Breyfogle (2005, p. 153) used videotapes of lessons to “confront teachers with their actual practice”. This approach was based on the “cognitive requisites” for enacting teacher change, proposed by Tobin and Jakubowski (1992):

- perturbation or uneasiness with the way things are;
- awareness that improvement requires change;
- commitment to move into action;
- vision of teaching;
- visualisation of the changes in the classroom and reflection as they are taking place; and
- reflection on teachers’ own practices and raising questions about their own actions in the classroom.

The three models described in this section provide useful frameworks for designing professional development for teachers. In particular, the models of Guskey (2002) and Clarke and Hollingsworth (2002) establish the need to consider teachers’ knowledge and beliefs, practices and student outcomes as important variables when evaluating the impact of professional learning. Weissglass’ (1994, p. 70) model recognises “obtaining emotional support” as another important factor in the change process. Reflection has been described as a “mediating process” (Clarke & Hollingsworth, 2002, p. 951) and as such plays a central role in engaging teachers in a review of their learning and a reconsideration of their practice.

To address the introduction of a new syllabus in Years 7 to 10 in NSW the *Certificate of Secondary Mathematics Education* (CSME) was designed for secondary school mathematics teachers. This course aimed to inform teachers of the changes to the new syllabus, provide a learning environment, which was conducive to discussion about their current practice, and to encourage teachers to reflect on their practice. Surveys were used to assist the reflective process. However, regular meetings between the participants aimed to build a community of practice so that discussions and sharing of experiences might provide emotional support and encourage more critical reflection.

Designing the Certificate of Secondary Mathematics Education (CSME)

The CSME aimed to support the introduction of a new syllabus for students in Years 7 to 10 in NSW classrooms. While much of the mathematical content remained the same as in previous documents, a fundamental change required teachers to rethink their practice in relation to several issues including:

1. descriptions of learning of mathematical concepts on a developmental continuum from Kindergarten to the end of Year 10;
2. removal of a formal three course structure in Years 9 and 10 and the recommendation

- that teachers design programs that enable students to be extended as far as possible;
3. integration of the process strand, Working Mathematically, into all of the content strands with the expectation that problem solving would become a central focus of learning [see Anderson (2005) for more details];
 4. inclusion of a range of technologies into all strands; and
 5. review of assessment in a standards framework with the introduction of “assessment for learning” as well as “assessment of learning” (BOSNSW, 2002).

The CSME sought to engage teachers in discussions about these issues through regular meetings with colleagues using experienced teachers, consultants and mathematics educators as facilitators.

Professional development can take many forms that include within school meetings as well as out of school conferences, workshops, and networking opportunities between schools. One approach involves school and university partnerships. Anderson & White (2004) describe several Australian studies that have focussed on the impact of professional partnerships between academics and teachers using the model of “critical friend” to explore teachers’ practices, and determine the level of implementation of new approaches including problem solving. As one example, Smith (2000) investigated five primary school teachers’ pedagogical practices in mathematics lessons and developed a teaching/learning framework for promoting thinking and understanding.

Such studies provide evidence that the support of an academic mentor is a productive strategy to assist teachers in implementing new approaches including problem solving and investigations, but the potential of this approach needs to be explored on a larger scale if change is to be realised for more teachers. New syllabus implementation requires that all teachers receive important messages about change in a shorter time frame. Typically this is achieved through conferences and meetings with syllabus developers where the message is delivered to representatives from schools. The Board of Studies in NSW conducted many of these meetings during 2004 with further opportunities offered through professional association conferences. This “training” approach is acknowledged as less successful in bringing about change in practice (Clarke, 1997; Clarke & Hollingsworth, 2002; Schifter, 1998). As teachers were still concerned about syllabus implementation, the CSME was designed to better address teachers’ concerns, bringing together a group of teachers who wanted to learn more about the new syllabus and its implementation.

One study that informed the design of the CSME was the Garet, Porter, Desimone, Birman and Yoon (2001) large-scale national survey into the effects of different characteristics of professional development on teachers’ learning. The survey of 1027 mathematics and science teachers revealed a set of

... three core features that have significant positive effects on teachers’ self-reported increases in knowledge and skills and changes in classroom practice: (a) focus on content knowledge; (b) opportunities for active learning; and (c) coherence with other learning activities. It is primarily through these core features that the following structural features significantly affect teacher learning: (a) the form of activity (e.g., workshop vs study group); (b) collective participation of teachers from the same school, grade, or subject; and (c) the duration of the activity.

Informed by this advice, the CSME incorporated:

- a focus on content from the new syllabus;
- active learning through discussions with colleagues and opportunities to try teaching ideas between the weekly workshops; and
- a focus on the need to program and plan the new syllabus.

In addition, the CSME included both a conference and workshops, encouraged more than one teacher from a workplace to attend, and involved ongoing meetings over a six-week period. Further consideration was given to Clarke's (1997) ten important principles to guide planning of professional development (see Appendix 1). In particular, the CSME focused on:

- addressing issues of concern and interest;
- involving groups of teachers from a number of schools;
- recognising and addressing impediments to growth at several levels;
- requiring active participation including the use of required readings;
- allowing time and opportunities for planning, reflection and feedback;
- affording opportunities for ongoing support from peers and critical friends; and
- encouraging participants to set further goals.

The first author of this paper was involved in the design of the new syllabus in NSW and was keen to provide additional support for mathematics teachers. With the assistance of others at the University of Sydney, she set out to design a course that would address the changes to the new syllabus as well as provide opportunities for teachers to work together over an extended period of time. As with any professional development endeavour, time was a prime dictate for CSME structure. Designed as a one-day conference, followed by six evening workshops, CSME provided twenty-four hours of face-to-face tuition outside of school hours. This both enabled the participation of practising teachers and satisfied the requirements for a postgraduate unit of study. The one-day conference included a keynote address about current issues followed by a range of workshops, facilitated by experienced secondary mathematics teachers, consultants, and mathematics educators. Participants were able to choose four workshops from the program. Six weekly meetings were then held, each with a focus on one aspect of the new syllabus including: algebra; technology; introductory calculus; measurement and geometry; problem solving and working mathematically; and assessment and reporting. The final evening also provided opportunities for feedback on the design and organisation of the course. Participants survey responses formed the basis of the evaluation, which is presented in the next section.

Evaluating Professional Learning

The models described earlier informed the design of the CSME as well as the evaluation tools. In particular, the Clarke and Hollingsworth (2002) model provided a framework for analysis of data. The "five critical levels of professional development evaluation" (Guskey, 1999, p. 78) were also used to inform instrument design and evaluation. These include:

1. participants' reactions,
2. participants' learning,
3. organisation support and change,
4. participants use of new knowledge and skill, and
5. student learning outcomes.

Evaluation of the CSME was primarily qualitative, conducted through self-report survey and semi-structured interviews. Whilst interview and survey questions related to all five of the critical levels listed above, there was a particular focus on Levels 1, 2 and 4. More accurate evaluations of Levels 3 and 5 were difficult to obtain due to the brevity of time between course conclusion and the final summative evaluation. However, there is potential to explore these at subsequent interviews.

The surveys were designed to assist teacher reflection on their learning. Eight surveys were used to evaluate the CSME – one at the conclusion of the conference, one at each of the six evening workshops, and a final summative survey involving evaluation of overall learning as well as the delivery and organisation of the CSME. The weekly surveys included a series of questions about the previous meeting as well as about the current evening’s workshop (see Appendix 2 for a sample). This section of the paper presents the background information for participants, discusses the responses to a selection of the survey questions, and analyses the interview responses of two teacher participants.

The Participants

The CSME was designed to cater for a broad audience, including: secondary mathematics teachers, coordinators of faculties, and mathematics consultants. Whilst targeting professionals from each of the three systems (DET, Catholic and independent), the majority of participants were from Catholic schools. To support their teachers, the Catholic Education Office, Sydney funded twenty-four of the thirty delegates. In total, there were 28 teacher participants representing fifteen schools with between one and three participants per school. Their professional roles varied accordingly and included: classroom teacher, Mathematics Coordinator, Assistant Principal, and Curriculum Coordinator. The remaining two participants were DET mathematics consultants. Attendees’ level of experience ranged from four to twenty-nine years, and female participants outnumbered their male counterparts by a ratio of 2:1.

The Surveys

The first page of the weekly survey was to be completed by participants at the beginning and the second page at the completion of each evening workshop (see Appendix 2). Extensive information was obtained through reading, coding and analysing the surveys of the 27 participants who completed all of the surveys. This section of the paper presents the data and analysis of a selection of the survey questions. In particular, data is presented which considers participants survey responses to each of:

- reasons for attending the CSME;
- learning as a member of a community of learners;
- implementation of ideas in classrooms;
- sharing ideas with colleagues;
- learning about aspects of the new syllabus and challenges to current thinking.

Reasons for Attending the CSME

Motivations for CSME participation were mixed, ranging from a current need to learn new ideas for implementation of the syllabus to longer-term goals. Accreditation was the primary goal for the majority of participants (31%) and took three forms: reclassification as a teacher of mathematics; acknowledgement of participation in a university endorsed course; and credence as an overseas trained teacher. The following responses from two participants were typical of teachers in this group:

I needed some sort of accreditation from an Australian university. People tend to be suspicious of foreign degrees/diplomas.

I have been teaching in a maths department for four years. I wanted something to help me [to] get reclassified to include maths teacher.

Other response categories, included:

- opportunity to stay in touch with developments in mathematics teaching (19%)
- chance to gain new ideas and strategies (15%)
- desire to learn more about the syllabus (15%)
- opportunity to improve skills (12%)
- chance to develop better quality resources (4%)
- had a friend doing it (4%).

Learning as a Member of a Community of Learners

To gauge whether participants had benefited from participation in a community of learners, the final summative evaluation required them to reflect on their learning as a member of the CSME community. The response was unanimously positive. Typically, respondents commented on the conversational aspect of the community:

Yes, definitely. Any contact and discussion of ideas with teachers from different schools is always valuable.

Other benefits cited were the motivational aspects of working with other teachers, confidence building and networking opportunities. For two delegates, participation in the learning community was so powerful it proved a catalyst for their enrolment in a Master of Education degree at the University of Sydney, rather than pursuing a degree through another university, which was to be offered using a distance-learning mode. As one explained:

... just the one day of actually being with other people and hearing how much more you get from listening to someone actually speak about something, rather than just a handout, and the conversation with the other people – the participants in the workshops – I realised that distance education was not the way for either of us ... and that this could be a good opportunity to look at what Sydney University had to offer.

Another participant who was the only representative from her school indicated that she felt very isolated since none of her fellow mathematics teachers were interested in the new syllabus or in new ways of teaching mathematics. During the CSME, she formed new friendships, exchanging contact details with several of the other younger teachers, and displaying enthusiasm each week as they arrived. For her, the weekly workshops offered far more emotional and professional support than she was receiving at her school. The evidence suggests that the CSME's community model was widely appreciated by participants and made a significant contribution to their learning. This also provides evidence of the importance of emotional support as described by Weissglass (1994).

Implementation of Ideas in Classrooms

Each week, participants were asked to report whether they had implemented any new teaching ideas from the previous week to identify evidence of Guskey's (1999) Level 4 (use of new knowledge and skill) and Clarke and Hollingsworth's (2002) professional experimentation. For four of the six weeks, about half of the respondents reported using some strategies. In week four, only 14% reported using any strategies but this is not surprising since the workshop on Calculus which was presented during week 3 was very specific to introducing this topic – the majority of teachers would not have been teaching this when the workshops occurred. In week 6, 85% reported using some of the strategies from week 5. The working mathematically and problem-solving workshop was very general with strategies involving a range of processes that could be applied across the curriculum to any topic currently being taught.

One teacher discussed the impact on students, reflecting Guskey's (1999) Level 5 (student learning outcomes) as well as Clarke and Hollingsworth's (2002) domain of

consequence:

The best I have done is to try to be more alert to the students ... I feel students are noticing it ... They have sensed me talking, instructing, teaching less and listening, watching, teaching more ... I think.

Negative responses most often related to the external constraints at school, ranging from a lack of preparation time to an absence of resources or equipment. For example, “Too many interruptions at school”, and “Unfortunately, we don’t have access to any of the equipment, but I would dearly love for my students to experience ‘enlightenment’”. Most teachers still expressed their intention to employ newly acquired knowledge and skills at a future date. As one explained:

We have not covered the units involving measurement and geometry yet, but I do intend to use them when we get to the topic.

These responses support a follow-up evaluation, three to six months after the CSME completion date. This would offer a more reliable picture of the impact of the professional development on participant learning as well as student learning outcomes.

Sharing Ideas with Colleagues

By documenting participants’ sharing of knowledge and skills with colleagues in school, this question determined the CSME’s impact at the organisational level –Guskey’s (1999) Level 3 (organisation support and change). Responses were overwhelmingly positive, with between 88-100% over the six-week period reporting they had shared new knowledge. There was, however, considerable variation in participants’ definition of sharing. At the most basic level, sharing was characterised as informal conversation. Whilst this was the most popular form of sharing during the earlier stages of the CSME (25% and 28% in weeks 1 and 2) this technique was superseded by more sophisticated sharing methods from week 3 onwards. Approaches included meeting with the faculty head to discuss the implementation of changes, introducing a method/idea into departmental planning, and demonstrating a new technique to other staff using a group of students.

Whilst colleagues’ reactions to participant sharing were generally positive, on occasion, participants met with a pessimistic response. As one participant experienced when sharing information from the week 2 technology workshop:

... most don’t believe that people (teachers) will teach for meaning unless assessment policies and procedures are changed to reflect this new perspective.

Whilst such instances were rare, they highlighted a perpetual obstacle facing participating teachers and evaluators of professional development: opportunities for teachers to implement new strategies/skills in schools that fail to support them; and the means by which providers of professional development evaluate whether a participant’s failure to implement new knowledge and skills is a consequence of poor program planning or external variables relating to the school context.

Learning about Aspects of the New Syllabus and Challenges to Current Thinking

In response to the question “what did you learn from this presentation and how do you plan to use the information to enhance the teaching and learning of mathematics”, almost all participants reported gaining new knowledge, skills and understanding each week. The comments were read and categorised as either referring to *personal* knowledge or *practical* knowledge. Personal knowledge included reference to beliefs and attitudes or new knowledge about mathematics or mathematics teaching and learning. Examples in this category include:

I have learnt a lot about how much I don’t know! It made me really think about the quality of my lessons and whether the students have been working mathematically rather than just getting answers.

The idea of abstraction and the effect this can have on our teaching; the theory of Van Hiele – I thought this was useful and I really hadn’t heard of this before.

Practical knowledge included new teaching ideas, tasks or activities, as well as practical ideas to aid implementation such as assessment strategies. For example:

Very rich tasks rather than relying on the textbook; introduce rates of change earlier on than I have done previously in my class. I will be more specific in my terminology gradient, dependent and independent variables.

Several respondents made comments about both types of knowledge. For example:

I learnt fantastic ways/strategies in implementing technology into the classroom. The motion detector was fantastic – the fact that it allows students to manipulate representations and actually “see” the mathematics, and with this it brings them meaning.

Challenging thinking is one way to promote deeper reflection and learning. Tobin and Jakubowski (1992) describe the need for “perturbation” or uneasiness with the way things are. With the exception of the final evening workshop, the majority of participants reported that their thinking had been challenged. Two examples of this follow:

Yes. It’s really made me think twice about how I might be working in algebra for some of my classes, and failing to really give them the opportunity to immerse in the big ideas.

Yes – especially the Van Hiele theory – it has made my expectations of what my Year 7 and 8 students can achieve more realistic.

From the surveys completed each week, the proportion of participants who made comments relating to each type of knowledge was collated. Table 1 presents the results (note that some teachers commented on both types of knowledge and are therefore represented in both columns) as well as the proportion of teachers who reported that their thinking had been challenged.

Table 1

Proportions of participants’ comments categorised as personal or practical knowledge, and proportion of positive responses as to whether the workshop challenged their thinking (% , N=27)

Weekly Session	Personal Knowledge	Practical Knowledge	Challenge to Thinking
Algebra	52	70	96
Technology	30	85	70
Introducing Calculus	52	74	56
Measurement and Geometry	55	59	52
Working Mathematically and Problem Solving	37	63	59
Assessment and Reporting	37	67	41

In their reflections, many respondents listed teaching strategies they will use thus indicating that they had gained practical knowledge for use in classrooms. Fewer teachers commented on personal knowledge, in particular their beliefs and attitudes. However, the data suggest that the CSME was successful in creating opportunities for teachers to engage with new mathematical content as well as new pedagogy. There is also evidence from teachers’ comments that the workshops have raised awareness about the need for improvements as teachers have made a commitment to the implementation of many of the ideas. Of course, this does not guarantee that change will occur and certainly several teachers noted that their school

did not have the resources to support such change, particularly in relation to the use of particular technologies. However, for many, participation in the CSME has provided a vision of what is possible and raised questions in teachers' minds about their practice.

As another measure of the success of the program, teachers were asked if the CSME had met with their expectations and if they would recommend the program to other secondary mathematics teachers. Ninety-three percent responded positively to both questions. To the first question, one response stated "Absolutely! The handouts, the background readings, the opportunity to have dialogue with colleagues" while another suggested "More than met my expectations. I have thoroughly enjoyed it and learned lots. I have ideas now about what I can teach and how I can teach it". To the second question, one response was "Yes. Need more teachers to be striving to teach students the way we have been taught/guided in this course".

To gain more detailed information about the impact of the program and the potential for change, respondents were asked if they were willing to be interviewed in the future. Nineteen of the 27 respondents agreed to be interviewed.

The Interviews

Two teachers were interviewed one month after completion of the CSME to gather further information about change in the three dimensions described by Clarke and Hollingsworth (2002) – personal domain, domain of practice, domain of consequence (see Figure 4 with illustrative examples). A semi-structured interview provided questions as discussion starters; each lasted about 30 minutes and was conducted by the second author. There was little need for probing as both teachers readily talked about their experiences in the course as well as its impact on their learning and practice.

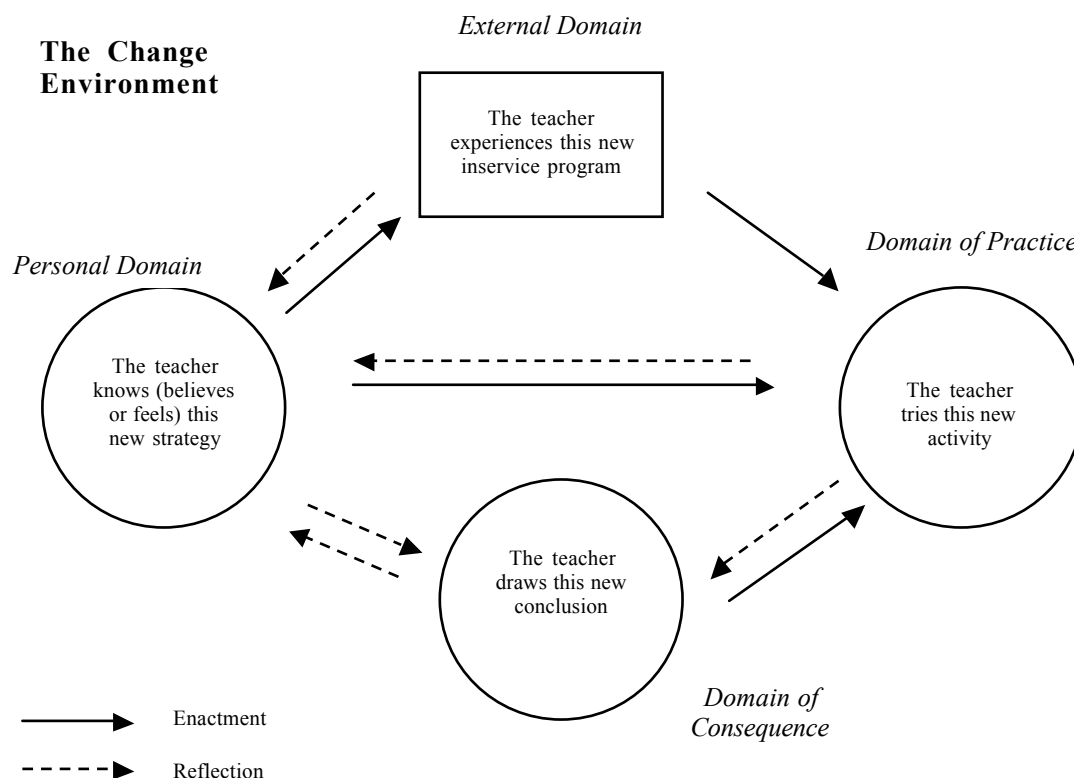


Figure 4. Interpreting the interconnected model of professional growth through illustrative

examples (Clarke & Hollingsworth, 2002, p. 957)

Mary attended the CSME with a colleague from a systemic Catholic girls' school, where she was teaching on the Year 7 and 8 campus. She had been teaching for 8 years, five of those in Australia. Kate had been teaching for more than twenty years in public schools in NSW and was currently a mathematics consultant. She attended with a fellow mathematics consultant, both of whom decided to attend all sessions of the CSME program after initially enrolling in just the one-day conference.

Mary's Challenge to Find Time for Reflection

Mary did not have Australian qualifications and wanted to gain further qualifications. As she was now permanently employed, she agreed it was less of a concern but decided that the course might offer worthwhile teaching ideas for her Year 7 and 8 classes. Her responses indicated that there had been a change in her personal domain as she reported on the potential for a continuing impact on her thinking and attitudes. She was surprised that for some topics she was not teaching, she needed to be aware of the necessary approaches:

For example, the pre-calculus thing, there were a couple of things that were mentioned during that and I thought that gosh, yes, that actually has repercussions all the way to the beginnings of algebra, and might actually inform the ways I introduce algebra.

As Mary was using a new self-paced program of learning in her classroom, she was unsure if she would be able to implement many of the practical ideas. The use of the new approach encouraged her students to be independent learners enabling her to better address student needs. However, as evidence of change in her domain of practice, she indicated that she had adapted a "favourite activity" from the Algebra workshop by creating a small group task rather than using it as a whole class activity.

When asked to recollect aspects of the CSME that had impacted on her knowledge and understanding, Mary mentioned the Working Mathematically evening, which affirmed her approach. She also indicated that it was the emotional support that helped her most as well as the time and space to devote to thinking:

... again the overall thing is being in a position to talk about maths, think about maths, think about teaching which we don't have. Just having that time, and that's why I quite liked a whole evening, a longish period, that you really were stepping back from the rest of your life ... I would have liked to have had more time to do the reflections at the time... you know immediately afterwards, because I found myself on Wednesday evening as I was going home thinking you know, this is great, I must think more about that, and read more about that, then Thursday morning I was right back in it again and it was gone.

These comments suggest Mary found the time invaluable to think about her practice and reflect on what she had been doing, something she described as "stepping back from the rest of your life" and wanting to "think more about that". She could see the value of reflecting on her learning.

Regarding enactment in the classroom, there appeared to have been insufficient time for Mary to implement the teaching ideas and to comment on the domain of consequence. However, Mary and the colleague from her school had shown some of the activities to fellow staff members in a faculty meeting. These had been well received and she acknowledged this enhanced and supported her growth. Future interviews might provide further evidence of change or growth networks as described by Hollingsworth (1999).

Kate's Challenge to Reflect on Practice

Kate had been thinking about enrolling in a masters degree program before the CSME began. She enjoyed the conference day and decided to complete the CSME and use it as a unit in the masters program by completing two assessment tasks. The first is a reflective journal entry on each of the workshops that includes evidence of learning from the workshop activities as well as the designated readings. The second is the design of a unit of work that is to be implemented in a classroom and evaluated from the students' as well as the teachers' perspective. Having made the decision to enrol in the masters program, Kate was required to complete both of these tasks as well as the weekly reflective surveys.

Her main motivation for attending was to learn new ideas for use with teachers in her role as a consultant. Kate indicated that she had indeed implemented many of the teaching ideas in her workshops and so there was evidence of change to her domain of practice. She had heard back from some of the teachers that they had successfully used the ideas in their classrooms so this could be considered as evidence of the domain of consequence. If the activities have been presented in a convincing fashion to secondary mathematics teachers and then successfully implemented by them, this would certainly lead to conviction by Kate that these activities were worthwhile.

In relation to her personal domain she reported that particular workshops had provided significant learning including the assessment and reporting workshop as well as the pervading theme of engaging students in the Working Mathematically processes. She stated

[the assessment workshop] gave a real depth of understanding for me [also] there was a real underlying theme of working mathematically – how you can use that, how you can use it effectively with students. That was the big story that I guess I then passed on to the colleagues ... it's great to have what I consider to be explicit examples that teachers can use in their mathematics classroom that are really engaging the kids in quality teaching.

In addition:

I think there are a couple of areas that I would definitely be doing differently when I get back into a classroom and I need to actually deepen my understanding of the ideas and really look into that more.

Kate indicated that her biggest challenge was to write the reflective journals for her masters unit since she found the process to be rather challenging. She stated

I've probably never written things in a reflective narrative form, and it's really interesting to sort of deepen my understanding of what I've got, and really reflect on what I'm getting out of it. So I'm really glad, at this point in time, that I am using it as a unit for the masters, because it is pushing me that extra step to really look at what I did get out of it and how I would use it and I think that's a level that I've probably not pushed myself to – I think I've just done things without questioning why or how else I could potentially do it. So I think that's very valuable.

As a mathematics teacher who was keen to get the “right answer”, Kate confessed that she was concerned about her reflection being “wrong”. She asked the first author to read her first reflection and provide feedback before she felt confident enough to continue.

Mary and Kate gained much from the CSME and both wanted to continue further study. Unfortunately Mary has decided not to continue because of lack of time. Kate has since submitted her reflections and they indicate deep learning. Further interviews are planned with other teachers from the group as well as additional interviews with Mary and Kate.

Reflecting on Teachers' Reflections

The interconnected model of professional growth proposed by Clarke and Hollingsworth (2002) was used to inform the development and evaluation of the CSME. There was evidence of change in the domain of practice, the domain of consequence and the personal domain for at

least some participants. However, a more detailed analysis to find evidence of change and growth networks would require in-depth interviews and observations with these teachers.

Teachers indicated on self-report surveys that they had learnt about new teaching approaches, they had shared some the ideas with colleagues, and they had appreciated belonging to a community of learners to share and discuss the changes to the mathematics syllabus. This was particularly powerful for at least one participant who reported feeling isolated in her school. However, others also enjoyed the emotional support and appreciated the friendly interaction each week. The first author attended all sessions of the CSME although she only facilitated one evening workshop. She observed the growth in enthusiasm, and community spirit within the group and by the end, noticed sharing of resources, exchanging contact details, and organising social gatherings. Several participants wanted to stay in touch through an email discussion group.

On the basis of responses to eight survey instruments and interviews with two participants the CSME was successful for several reasons including motivating the teachers to engage with many of the issues raised in the changes to the new mathematics syllabus. Teachers were encouraged to reflect on practice through the surveys as well as through conversations with colleagues and other participants. While the instruments did provide evidence of reflection at the level of using new teaching ideas such as tasks and activities (referred to here as practical knowledge), there was less evidence of deeper reflection on personal knowledge including beliefs and attitudes. It is possible that asking for reflective responses at the beginning and end of each session provided insufficient time for deeper reflection, or that the questions posed did not illicit such responses. We tend to assume that teachers are comfortable with the reflective process and yet teachers' responses suggest that further modelling or scaffolding may be required.

While the CSME addressed each of the ten principles described by Clarke (1997) (see Appendix 1), the evaluation has highlighted several aspects which need to be considered if the CSME is to be offered in 2006. As the CSME is currently designed, it is possible that six weeks is too short, particularly if change is to be realised in classrooms. Unless participants were enrolled in the masters program there was no real commitment to action. Anecdotal evidence suggests that for those teachers who were supported by colleagues from the same school, at least some of the ideas have been trialed in classrooms. This could be further investigated through interviews. Finally, the CSME was conducted at the University of Sydney, away from teachers' workplaces. While at least some research suggests that professional learning is more successful if undertaken in the workplace, we are not convinced this was an issue for this course. However, we would like to consider the possibilities of delivery of such professional learning opportunities at other venues, possibly involving clusters of schools.

References

- Anderson, J. (2005). Working Mathematically in NSW Classrooms: An Opportunity to Implement Quality Teaching and Learning. In M. Coupland, J. Anderson, & T. Spencer (Eds.), *Making Mathematics Vital* (pp 53-59), Proceedings of the 20th biennial conference of the Australian Association of Mathematics Teachers. Sydney: AAMT.
- Anderson, J., & White, P. (2004). Problem solving in learning and teaching mathematics. In B. Perry, G. Anthony, & C. Diezmann (Eds.), *Research in Mathematics Education in Australasia 2000-2003* (pp. 127-150). Flaxton, Qld: Post Pressed.
- Artzt, A. F., & Armour-Thomas, E. (2002). *Becoming a reflective mathematics teacher*. Mahwah, NJ: Lawrence Erlbaum Associates.

- Board of Studies NSW [BOSNSW] (1996). *Mathematics Years 9-10 Syllabus - Advanced, Intermediate and Standard Courses*, Sydney: BOSNSW.
- Board of Studies NSW (2002). *Mathematics Years 7-10 Syllabus*. Sydney: BOSNSW.
- Breyfogle, M. L. (2005). Reflective states associated with creating inquiry-based mathematical discourse. *Teachers and Teaching: theory and practice*, 11(2), 151-167.
- Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18(8), 947-967.
- Clarke, D. M. (1997). The changing role of the mathematics teacher. *Journal for Research in Mathematics Education*, 28(3), 278-308.
- Ewing, R. A. (2002). Framing a professional learning culture: An Australian case study. *Curriculum Perspectives*, 22(3), 23-31.
- Garet, M. S., Porter, A. C., Desimone, L., Birman, G. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4), 915-945.
- Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher*, 15(5), 5-12.
- Guskey, T. R. (1999). *Evaluating professional development*. California: Corwin Press.
- Guskey, T. R. (2002). Professional development and teacher change. *Teachers and teaching: Theory and practice*, 8(3/4), 381-391.
- Hollingsworth, H. (1999). *Teacher professional growth: A study of primary teachers involved in mathematics professional development*. Ph.D. thesis, Deakin University, Burwood, Victoria, Australia.
- Joyce, B., & Showers, B. (1995). *Student achievement through staff development*. White Plains, NY: Longman Publishers.
- Lopez-Real, F. (2003). Collaborative reflection through sharing significant incidents. In A. Peter-Koop, V. Santos-Wagner, C. Breen, & A. Begg (Eds.), *Collaboration in teacher education* (pp. 235-252), Dordrecht: Kluwer Academic Publishers.
- Schoen, H. L., Cebulla, K. J., Finn, K. F., & Fi, C. (2003). Teacher variables that relate to student achievement when using a standards-based curriculum. *Journal for Research in Mathematics Education*, 34, 228-259.
- Schifter, (1998). Learning mathematics for teaching: From a teachers' seminar to the classroom. *Journal of Mathematics Teacher Education*, 1(1), 55-87.
- Smith, T. (2000). Bridging the research-practice gap: Developing a pedagogical framework that promotes mathematical thinking and understanding. *Mathematics Teacher Education and Development*, 2, 4-16.
- Tobin, K., & Jakubowski, E. (1992). The cognitive requisites for improving the performance of elementary mathematics and science teaching. In E. W. Ross, J. W. Cornett & G. McCutcheon (Eds.), *Teacher personal theorising: Connecting curriculum practice, theory, and research*. Albany, NY: State University of New York Press.
- Weissglass, J. (1994). Changing mathematics teaching means changing ourselves: Implications for professional development. In D. B. Aichele & A. F. Coxford (Eds.), *Professional development for teachers of mathematics* (pp. 67-78). Reston, VA: National Council of Teachers of Mathematics.
- Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. New York, NY: Cambridge University Press.
- Wilson, M., & Cooney, T. (2002). Mathematics teacher change and development. In G. C. Leder, E. Pehkonen, & G. Torner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 127-147). Dordrecht: Kluwer Academic.
- Zeichner, K. M. (2003). Teacher research as professional development for P-12 educators in the USA. *Educational Action Research*, 11(2), 301-325.

Appendix 1

	Ten important principles of professional development (Clarke, 1997)	<i>Certificate of Secondary Mathematics Education</i> , The University of Sydney
1.	Address issues of concern and interest, largely (but not exclusively) identified by the teachers themselves, and involve a degree of choice for participants.	Issues were identified from other workshops conducted by the first author. Teachers were able to choose workshops on the conference day.
2.	Involve groups of teachers rather than individuals from a number of schools, and enlist the support of the school and district administration, students, parents, and the broader community.	The involvement of CEO Sydney, meant that two or three teachers from several schools in that Diocese participated in the Certificate course.
3.	Recognise and address the many impediments to teachers' growth at the individual, school and district level.	Listening to teachers' stories and concerns about their contexts assisted the development of a learning community.

4.	Using teachers as participants in classroom activities or students in real situations, model desired classroom approaches during inservice sessions to project a clear vision of the proposed changes.	Teachers were encouraged to try new ideas between sessions and to share their experiences.
5.	Solicit teachers' conscious commitment to participate actively in the professional development sessions to undertake required readings and classroom tasks, appropriately adapted from their own classroom.	Teachers were encouraged to discuss experiences, share understandings, read about the ideas, and regularly reflect on their learning.
6.	Recognise that changes in teachers' beliefs about teaching and learning are derived largely from classroom practice: as a result, such changes will follow the opportunity to validate, through observing positive student learning, information supplied by PD programs.	This is an ongoing aim of the course although it was probably not achieved in the six-week timeframe.
7.	Allow time and opportunities for planning, reflection, and feedback in order to report successes and failures to the group, to share "the wisdom of practice", and to discuss problems and solutions regarding individual students and new teaching approaches.	Each week, teachers reflected on their learning from the previous session and were encouraged to talk with peers about what they had done. As teachers formed friendships, this increased as the course progressed.
8.	Enable participating teachers to gain a substantial degree of ownership by their involvement in decision-making and by being regarded as true partners in the change process.	A collegial atmosphere developed as the CSME continued.
9.	Recognise that change is a gradual, difficult, and often-painful process, and afford opportunities for ongoing support from peers and critical friends.	Groups of teachers began to support each other and to share resources and ideas. There was an exchange of contact details and ongoing email communication between some teachers.
10.	Encourage participants to set further goals for their professional growth.	Several of the participants enrolled in a Master of Education degree as a consequence of the Course, which can be credited towards one unit with the completion of two assessment tasks.

Appendix 2

Participant Reflection on Learning Evening Workshop No. 3 – Introducing Calculus

Background Information:

- Name (optional) _____
or Personal Code (from birthday, e.g. 4 August, 1951 would be 040851) _____
- How many years have you been teaching mathematics? _____
- School (optional) _____ Role at school _____
- Since you attended the evening workshop on *Technology* on 23 February 2005, have you implemented any of the ideas in your classroom? If so, what did you learn from this?

5. Have you shared any of the things you learnt from the *Technology* workshop with colleagues?

6. This evening's workshop is about *Introducing Calculus*.

Please answer the following questions **before** the workshop begins, by circling the most appropriate descriptor.

How would you rate your knowledge and understanding of *Introductory Calculus* from the syllabuses?

Very good	Good	Satisfactory	Unsatisfactory
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How confident do you feel when you teach *Introductory Calculus* from the syllabuses?

Very confident about all aspects of the topic	Confident about most aspects of the topic	Confident about some aspects of the topic	Not confident about teaching this topic
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Evening Workshop – *Introducing Calculus*

7. What did you learn from this presentation and how do you plan to use the information to enhance the teaching and learning of mathematics?

8. Has this session challenged the way you think about teaching calculus? If so, in what ways?

9. Based on your learning, please circle an overall rating for this workshop:

Very useful	Useful	Somewhat Useful	Not Useful
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10. Please answer the following questions **after** the workshop, by circling the most appropriate descriptor.

How would you rate your knowledge and understanding of *Introductory Calculus* from the syllabuses?

Very good	Good	Satisfactory	Unsatisfactory
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How confident do you now feel about teaching *Introductory Calculus* from the syllabuses?

Very confident about all aspects of the topic	Confident about most aspects of the topic	Confident about some aspects of the topic	Not confident about teaching this topic
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11. Do you have any other comments or feedback on the evening workshop?

Thank you.