CRITERIA FOR DESIGN AND EVALUATION OF INNOVATIVE MATHEMATICS LEARNING ACTIVITIES

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ABSTRACT
In this paper I will consider various approaches to program design and delivery in mathematics education and then reflect on the work of Borba and Villarreal (2005) in relation to their concept that humans work with technology as it applies to problem solving and modelling including project work in the mathematics classroom. I will also draw on my recent post-doctoral work to suggest some possible criteria for the design and evaluation of mathematics programs for school, vocational, and tertiary students.

THE DESIGN PROCESS
For several years I have been lecturing in a subject called Program Design and Delivery and part of the study entails consideration of underlying assumptions, purposes, concepts, and methods used in the process. There are many approaches to educational program design — such as technicist or traditional, constructivist or learner-focused, socio-cultural or contextually situated with a focus on communication, or critical with a political focus — and whichever approach is taken will have implications for students’ learning outcomes. Each approach can be identified by asking specific questions:

- What assumptions are being made by the program designer — that is, what are the cognitive, affective and values foundations for the program? What is known about the learners and is this important?
- What kinds of purposes and priorities are being pursued and/or intended to be realised? There may be unintended effects as well as intended effects.
- What kinds of concepts are being used in this approach? What concepts are central?
- What methods are being used to achieve the intended educational design and delivery?

As an example, the 1949 publication by Ralph Tyler outlined a simple four-stage model for planning an educational program:

1. define objectives, decide on educational purposes;
2. identify and select learning experiences to achieve those purpose;
3. organise learning experiences for effective instruction; and
4. evaluate the effectiveness of the learning experiences.

This could be considered a technicist model in that the learner and the community are invisible, as indeed are the politics; the focus is on the curriculum, teaching, and assessment. Nevertheless, the model itself is still widely employed around the world, at all educational levels. Following this approach to planning, project work for mathematics students would specify in advance not only the intended learning outcomes, but also each of the steps along the way.

Many education systems today have adopted, in the rhetoric at least, a constructivist paradigm, which holds that learners construct their own knowledge rather than having it transmitted via a teacher or a textbook. This approach, however, leaves out the social, cultural, and political perspectives, with its prime focus on the individual learner. Under this
paradigm, project work for mathematics students would concentrate on them achieving the prescribed mathematics content, perhaps even prescribing or suggesting relevant mathematical processes, encouraging them to construct new mathematical knowledge with the assistance of practical activities, technological support (via ICTs) and where possible, discussion and dialogue with others.

By contrast, a socio-cultural perspective would relate projects directly to the personal worlds of the students, and a critical perspective would encourage them to question decisions made elsewhere that directly or indirectly impact upon their lives in ways that might be disempowering to them and/or members of their community, local or global. Whereas the constructivist paradigm has as the main goal the individual learning certain mathematics, the last two perspectives tend to use the mathematics as a tool (or mediating artefact) in the pursuit of some extra-mathematical goal. This is typical of many workplace mathematics programs, among others. Examples of these latter approaches in formal education settings in Brazil and Argentina may be found in the work of Borba and Villarreal (2005) and in Denmark (e.g., Skovsmose, 1994).

**INNOVATIVE ACTIVITIES IN THE MATHEMATICS CLASSROOM**

Borba and Villarreal (2005) view technology as one of the many possible artefacts for use in the mathematics classroom, especially when it is used in supporting teachers and students to work together in order to empower learners young and old to participate fully in the worlds they inhabit, now and in the future. With a view to empowering learners by giving them as much responsibility as possible for their own learning, they advocate a strategic role for the modelling and solution of problems seen as important by the students. Believing that access to technology is a right of, and necessary for, citizenship, they intend that mathematical activity will be supported wherever possible by information and communication technologies.

As I have noted in my own work (FitzSimons, 2006a), the role of computers is well recognised at the lower cognitive levels of skill development and reinforcement (drill-and-practice) as well as assisting in the development of conceptual understandings through the use of appropriate software packages, it is less commonly recognised for its potential in assisting personal communication, locally or internationally, accessing relevant up-to-date data, and enabling the development of new knowledge for the learners concerned. At this last, highest level, I am referring to problem solving and modelling, problem posing, and project work, including the use of the world wide web.

Once it is decided that technology is relevant for education, Borba and Villarreal (2005) recognise the importance of the need to co-ordinate multiple representations made available through computer software — such as everyday language, symbolic language, tables, and graphs; even body movements can be coordinated with these standard representations. Borba and Villarreal’s perspective is that there is an ‘intershaping relationship’ where technology is seen as shaping humans, and humans as shaping technology. They believe that “students should be exposed to these new technologies of intelligence so that the knowledge which is produced in schools and universities is not disconnected from the rest of society …” (p. 56). Their research also has the political agenda of focusing on what students and teachers can do rather than on what they cannot do. Also, rather than just one mathematics, which excludes many, they advocate that new collectives of humans-with-media develop different mathematics. Such a proposition extends across all levels of mathematics education. (See FitzSimons, 2007 for a complete review of the book.)
In the compulsory, vocational, and tertiary education sectors, mathematics teachers are encouraged to work in collaboration with the other staff to devise projects that maximise the potential for students to learn and to use non-trivial mathematics in contexts which are meaningful to themselves. Such projects may be simulated where necessary for ethical, safety, financial, etc., reasons. Possibilities for project work being given recognition through a substantial weighting in the assessment process depend of course upon the degree of regulation.

**CRITERIA FOR DESIGN AND EVALUATION OF MATHEMATICAL ACTIVITIES**

Adopting a socio-cultural perspective, in the planning stages it would also be useful to see how so-called generic skills such as those I discussed at CIEAEM 58 might be incorporated (See FitzSimons, 2006b, for elaboration).

- Collecting, analysing and organising information
- Communicating ideas and information
- Planning and organising activities
- Working with others and in teams
- Solving problems within realistic constraints
- Using technology
- (Inter)cultural awareness and understanding

The Australian list also included *Using mathematical ideas and techniques* and naturally this would be an expectation in any mathematics class. However, project work also provides an impetus for the learning of new ideas and techniques as well as applying and refining pre-existing ones. At the evaluation stage, one question could be: “Which competencies were demonstrated and how well were they addressed?”

In FitzSimons (2006a) I drew upon activity theory to propose a framework for tertiary and other mathematics educators who intend to utilise technology in their programs. Following the work of Engeström (1987), there are six inter-related elements of a culturally mediated activity system: the object, subject, mediating artefacts (signs and tools), rules, community, and division of labour. In designing and evaluating innovative activities, with or without ICTs, teachers or other designers need to address questions such as:

- Who are the learners? [Other stakeholders apart from students may also be learning!]
- Why are they learning? [What has brought them to this point at this time?]
- What are they learning? [What are the intended learning outcomes?]
- How do they learn? [What are the social, cultural, historical, psychological etc. dynamics? What is the role for technology? What other mediating artefacts are available?]

Particularly in the case of technology utilisation, it is critical that computer software programs go beyond the ubiquitous level of skills practice and reinforcement. This is an important but limited role for the technology. Much developmental work has been done in recent years to adapt computer technology for use in assisting conceptual understanding with specialised packages (e.g., Cabri, Logo) as well as devising teaching strategies with generic packages designed primarily for the workplace (e.g., spreadsheets, computerised algebraic systems [CAS], commercial statistics packages). However, there is also a critical role for ICTs in supporting communicative actions between learners and with the external world beyond the classroom. They can also support creativity and the development of (locally) new knowledge for the learners as they pose their own questions and attempt to find workable solutions. These last two roles are much less commonly included in formal mathematics education, but
provide the learners with an opportunity to develop the kinds of skills which will benefit them in the worlds they inhabit, now and in the future.

At the evaluation stage, the questions should not only address the hierarchical level/s of the activity, but also how well the activity took into account the four questions concerning learning listed above — who? what? why? how?. Other questions might include:

- What were the mathematical objectives and outcomes of the activity?
- How well did it address the particular interests of the learner/s?
- What was the role of technology and other artefacts?
- How well were these supported by the learner’s community (at school & elsewhere)?
- Who did what (i.e., division of labour)?
- Were the mathematical rules understood? Were the regulative rules governing behaviour etc. appropriate?

As a final evaluation of the program, two further questions might be asked:

- Were there any unintended consequences (positive or negative)?
- What might be done differently next time?


**CONCLUSION**

This paper has drawn upon a very large body of work undertaken from 2003-2006, which included an extensive literature review into adult numeracy/mathematics, pedagogy and adult learning principles, and the use of electronic technologies as tools for learning as well as in various forms of calculation and communication. The final product, based on activity theory as interpreted by Engeström (1987), offers a large and complex range of questions for designers and developers of numeracy or mathematics education programmes for adults. These are placed under the six categories object, subject, mediating artefacts (signs and tools), rules, community, and division of labour, and may be used by teachers, teacher educators, and researchers. Feedback is welcome!

In answer to the conference discussion paper question: “How to raise awareness, particularly among decision makers and in the academic community?” I would suggest that the learners’ local communities might well provide an excellent resource for the innovative kinds of project described above. At home, families and friends might even become engaged with this new approach to learning and doing mathematics. Policy makers who attempt to show themselves abreast of the times, searching for that elusive solution that will raise their particular country’s international standing and supposedly save money at the same time are naturally drawn to the idea of technology. However, they need to be led towards an understanding of its potential educational rather than economic costs and benefits alone. Politicians and the local press could be invited to view the display of presentations of results of innovative projects carried out by students.

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