A curriculum design approach which creates increased opportunity

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Abstract: *There are very few curricula which are robust enough to succeed in diverse cultural settings over an extended period of time. The Montessori curriculum is an example of one that has – it has been adopted on every continent, it has sustained itself for over a century, and its success has been validated by well controlled scientific studies. Importantly, also, the Montessori curriculum has proven to be very effective when used with equity groups such as the mentally handicapped and those in low socio-economic groups. This paper looks at the curriculum design approach used by Montessori and extracts the key underlying principles used in the design process. The paper then discusses how one can use the Montessori approach for curriculum refinement in a first year university unit.*

Introduction

In the late 19th century Maria Montessori became the first female to graduate as a doctor in Italy. Not long after graduating she began working with the marginalised in society. Initially she worked with mentally handicapped children, and after observing these children for some time, came to the conclusion that their problems were more pedagogical than medical. She therefore set about devising a curriculum which could meet their needs. After devising such a curriculum and using it with the children the progress was remarkable. The mentally handicapped children started to score better than the non-handicapped children in national tests (Kramer, 1988). This outcome became known as the "first Montessori miracle". Montessori then shifted her attention to another marginalised group - the poor. She ceased practicing medicine and began working with unruly children in a poor neighbourhood of Rome.

Montessori's work began with children whose ages ranged from about 2.5 years to 12 years. She was quick to realise that children had different dispositions to learn at different ages, and designed her programs accordingly. She noted, for example, that 0-6 year old children had particularly "absorbent minds". This latter phenomenon was subsequently verified by neuroscientists (Kilgar & Merzenich, 1998). These neuroscientists showed that young children (unlike adults) experience a chemical release which allows them to effortlessly learn in deep and lasting ways, even without highly focused attention. That is one reason why children learn languages so easily. Montessori also noted that 0-6 year olds were very sensorial, and so her programs focused heavily on 'education of the senses'. That is, her programs allowed children to work with physical materials as they learned. She found that 6-12 year olds had different learning dispositions to the younger children. The 6-12 year olds had much greater needs for 'community' and also had greater dispositions towards using their reason and imagination. She therefore tailored the learning environments accordingly.

While Montessori developed theoretical understandings of learning within adolescents and older teenagers, she did not develop teacher training programs for these types of learners, nor did she devise detailed educational plans for them (although others did, based on her ideas).

In 2005 Angeline Lillard wrote an award winning book called "Montessori, the science behind the genius" (Lillard, 2005). In that book Lillard showed that almost all of the pedagogical strategies and curricular outputs devised by Montessori were later validated by scientific testing. A study published in *Science* by Lillard and Elsequest also showed that when Montessori education is strictly implemented the children develop better academic and social skills than children in traditional schools (Lillard & Elsequest, 2006). Additional validation of Montessori's work has come from the "Early Years Study" (McCain and Mustard, 1999). This report, commissioned by the Province of Ontario in Canada, brought together evidence from many disciplines including sociology, neuroscience, paediatrics, epidemiology and developmental psychology. The data in chapter one of the report, provides external scientific support for every all of Montessori's key learning principles.

This paper examines Montessori's work from a different angle to that previously considered by authors such as Lillard. Rather than critically examining the curriculum outputs, this paper examines the curriculum design approach of Montessori. It will be seen that her design strategy anticipated much of the evidence compiled about learning and teaching in the latter part of the 20th century. The implications for contemporary curriculum design within Engineering are then discussed.

The key Montessori curriculum design principles

Curriculum Design Principle 1: There are intrinsic natural forces impelling students to learn and the key job of the curriculum designer is to understand these natural forces and harness them. If this is done the learning will flow in a relatively effortless way.

Evidence for Curriculum Design Principle 1: Mikhail Csikszentmihalyi was a University of Chicago Professor who became famous for his work on the concept of "flow". He articulated this notion of flow in the 1960s and researched it thoroughly in the decades which followed (Csikszetnmihalyi, 1996). This state of flow is a state in which an individual (or group) is so absorbed in their learning and achievement that they lose track of time and their surroundings. That is, flow is a state in which the natural forces of learning and achievement are empowered. Moreover, research studies have found a strong correlation between flow and improved learning (Csikszetnmihalyi & Rathunde, 1993).

After many years of research on the phenomenon of flow, Csikszentmihalyi became aware that the Montessori method seemed to set up very favourable conditions for flow to be achieved. He and a co-worker performed a multi-year study to compare Montessori schooling with traditional education. They found evidence that Montessori schools did indeed create significantly better flow than their traditional counterparts (Rathunde & Csikszetnmihalyi, 2005a & b).

Curriculum Design Principal 2: The curriculum design must begin and sustain itself by acquiring large quantities of observational data and other scholarly information. Montessori's curriculum design process centred around the designer observing and learning from the student during the design process. Her rule was "follow the child". In reality, Montessori tried to "follow *every* child" and allow *all* of the students (who were all at different achievement levels) to move forward at different rates and in different ways.

Evidence for Curriculum Design Principle 2: Research has shown that expert teachers learn and adapt as they teach (Borko & Livingstone, 1990). To foster good teaching and curriculum design, then, one needs approaches which foster learning during the teaching and curriculum design process, just as Montessori recommended. The evidence also shows that as experts solve a problem (such as how to design a curriculum) they tend to accumulate and process a large amount of data before making decisions (Ericsson & Simon, 1993). This is known as forward-directed reasoning. With this type of reasoning a large amount of pattern matching is invoked, along with a sequence of if-then-else production rules (Ericsson & Simon, 1993). Montessori focussed her efforts in curriculum design on a forward-directed reasoning approach in which she learned by carefully observing the children, as well as consulting the wisdom of esteemed educators from the previous 200 years.

Montessori also encouraged the development of forward directed reasoning in students, by placing a wide variety of relevant data before them, but encouraging them to make their own links and not demanding that they arrive quickly at a narrow hypothesis.

Curriculum Design Principal 3: The curriculum should have no rewards, punishment or grades. As part of Montessori's commitment to allowing students to move forward at different rates there were no rewards, no punishments and no grades or summative assessment. She believed that rewards and punishment would be demeaning to the self-image and autonomy of the individual. If extrinsic rewards were the sole motive for making progress in the learning, the student would not develop the necessary intrinsic motivation to take responsibility and control of their own learning. The experience of success in mastering self-initiated tasks, she argued, would be sufficient motivation for genuinely human learning.

Evidence for Curriculum Design Principle 3: Montessori's decision to eschew rewards, punishment and formal summative assessment is supported by clear evidence that these components usually decrease intrinsic motivation for learning (Decli et al, 1999).

Curriculum Design Principal 4: The final curriculum must be easy for teachers to implement and it must be easy for students to use and it must produce effective learning. One of the key end products of Montessori's curriculum is a set of self-correcting materials which the students can use when they are ready. Readiness is signalled by the student having mastered less complex sets of materials, thus indicating readiness for more advanced challenges. All of the materials are easy to use and provoke self-directed learning and discovery, but at the same time benefit from feedback which has been deliberately inserted by the curriculum designer. Moreover, the discovery component of the learning wisely occurs within a goal-free (open-ended) problem solving environment rather than in an environment with explicitly stated goals (Mawer & Sweller, 1982).

The self-correcting materials in the Montessori curriculum are easy for students to use and require very little by way of explanation from the teacher. The teacher typically asks open-ended questions which indicate possible areas of investigation where the students can find answers for themselves, rather than be offered definitive solutions. Because the teacher spends relatively little time explaining procedures they have substantial time to observe, reflect and learn from the students as they engage with the curricular materials.

Evidence for Curriculum Design Principle 4: In the Montessori system the curriculum is not difficult to implement since teachers have to do very little didactic instruction. They are required, on the contrary, to focus on observing, reflecting and learning. The teachers are also trained to act on their reflections to guide students on how to use materials that will let students work out their own answers. These teaching practices are in line with the evidence which shows that i) teachers need to learn as they teach (Borko & Livingstone, 1990) and ii) reflection is particularly helpful for improving teaching and learning (Palincsar & Brown, 1984). In Montessori education students i) learn by doing in a semantically rich and feedback rich environment and ii) learn via the intrinsic worked examples provided by the self-correcting materials. Over thirty years of research in the cognitive sciences has shown the effectiveness of i) learning by doing in semantically rich and feedback rich environments (Anderson et al., 1995), and ii) learning by example (Anderson et al, 1997). Such learning environments are also easy for students to engage with (Rathunde & Csikszetnmihalyi, 2005a & b).

The implications for engineering education

The Montessori approach to curriculum design has had substantial demonstrated success with equity groups as well as with mainstream groups in primary education. This paper explores the question of whether Montessori's curriculum design approach can be gainfully employed in tertiary education. Clearly, her approach cannot be used in its purest form because tertiary teachers are under many constraints and are not at liberty to change curriculum design at will. Most tertiary teachers cannot, for example, eliminate grades and summative assessment. They also normally have to work within established curriculum design frameworks. Nonetheless it is possible to incorporate some of the curriculum design principles from the Montessori method, at least at the 'micro level' of curriculum design. The following is a set of strategies which implements such a micro-level curriculum design in tertiary settings.

1. Adopt a mentality of observing and analysing student behaviour and student feedback in the light of research evidence to determine what causes 'flow'. i.e. "follow the students and rigorously pursue the evidence". This effectively implements a forward directed reasoning approach to micro-level curriculum and materials development.
2. Formative assessment should be emphasised as far as possible, rather than summative assessment.
3. Employ self-correcting curricular materials which are semantically rich and feedback rich.

The implementation of the above strategies in a first year engineering unit at QUT is discussed below.

Implementation within a first year Electrical Engineering unit:

Strategy 1: To source feedback on the effectiveness of the unit from students, the unit co-ordinator went around the class every lecture talking to students individually. He usually talked to more than twenty students individually every lecture. To obtain further feedback the unit co-ordinator spoke with the tutors every week and asked them for their perceptions on how students were travelling in tutorials. He also asked them whether they had any suggestions on how the unit could be improved.

The unit co-ordinator also regularly checked the literature to find evidence about what influences genuinely increased engagement and increased achievement in students. After finding evidence that was relevant and practically applicable, he discussed possible new interventions with the tutors, and then trialled the new initiatives as appropriate. He then got feedback on these initiatives from students and tutors. To facilitate clarity in this process (for himself and others) he compiled his findings and methods in a book (O'Shea, 2010). The conclusions from (O'Shea, 2010) were that 'flow' could be fostered in first year engineering units through:

A. care and belief in students,

B. humour,

C. surprise,

D. opportunities for peer interaction,

E. situating some of the learning within the culture of the students,

F. varied activities, varied locations and varied curriculum materials,

G. opportunities to regularly practice what was being taught, and

H. opportunities to apply what was being learned to real world scenarios.

These elements were all introduced into lectures, tutorials and project work.

Strategy 2: As pointed out in (Lillard, 2005), by the time students get to high school or university they are strongly conditioned to learning based on assessment rewards. This is a regrettable state of affairs which makes it very difficult to guide mainstream learning without using summative assessment. It is realistically possible, however, to stimulate intrinsically motivated learning in new domains where students have not yet developed strong associations with summative assessment. In the first couple of semesters of engineering, for example, the domains of engineering design, creativity, reflection and are relatively new for students. As per Montessori's approach, it is possible to draw out the natural thirst for learning in these areas by providing the appropriate supporting environment.

To stimulate the right kind of environment for engineering design and creativity, students were given an open-ended project in which they created some product that would be practically useful to someone else. They were given the freedom to choose the type of product and they decided what the nature of their contribution would be. They could choose to design and build hardware, generate software, create a creative human-computer interface or any combination of these three. This project was deliberately given a low summative weighting (of 15%) so that there was relatively little extrinsic reward for putting in a lot of effort. There was a lot of formative support and encouragement given, however, via help sessions. Despite the relatively low summative weighting, the students typically engaged with the project very enthusiastically.

Creativity and reflection were also stimulated by regularly providing fascinating examples of engineering innovation and by discussing the reflective processes which birthed these innovative breakthroughs. Examples of such engineering creativity were sourced from *IEEE Spectrum*, a magazine dedicated to showcasing promising breakthroughs.

Strategy 3: Various self-correcting curricular materials were used. These materials included:

A. An assignment that required students to solve problems in multiple ways. This enabled students to get 'self-feedback' on whether they were correct or not.
B. Video tutorials where students could work through problems at their own pace and check answers as they needed to.
C. Multiple-choice quizzes which provided immediate feedback. Very recently, the PeerWise software program has been introduced for this purpose. This has allowed students to generate and rate one another's quiz questions.
D. Electronic game shows which provided immediate feedback (eg. "Who wants to be an electrical engineer?" and "Search for a super-engineer" (O'Shea, 2010)).

Results

Strategies i) to iii) have been used in the first year Electrical Engineering unit at QUT for the past 4 years. Typically, the class sizes involved have been around 600. Below are some preliminary findings.

Qualitative feedback: Many comments in anonymous end-of-semester feedback have indicated that "flow" has been achieved. Comments have included "made me want to learn", "when I'm having fun I can learn better", "gave us a lecture that we could really look forward to". The staff students liaison committee meetings have lauded the self-paced curricula materials every year and have called for wider uptake of these types of these materials by academic staff.

Quantitative feedback: The average overall unit satisfaction scores in the most recent relevant running of the unit were 4.3/5.0, having risen from 3.7/5.0 three years earlier. During that three year period the faculty average was consistently around 3.5/5.0.

It is important to acknowledge that it is not possible to prove causality between the improved scores and the implementation of Strategies 1 to 3, since there were many confounding influences influences. At the same time, the curriculum design approach does not appear to have done much harm. Likewise, it is difficult to quantify the impact of the micro-curricular changes on equity groups with certainty, but the strategies do not seem have done any substantial harm. Attrition rates in the faculty for Indigenous students (a key equity group) have decreased over the past 5 years by a factor of about 4.

Conclusions

This paper has identified a curriculum design approach (due to Montessori) which has been very successful in enhancing the success of equity groups within primary education. The paper has articulated the key underlying principles in the design approach, and these principles have been applied to the context of first year engineering 'miro-curricular' design. The preliminary findings from this exercise have been positive.

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