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Towards a Framework for Exploring Children’s Analytical Thinking and Creativity in Technology

Coral Campbell, Alistair Webster, Beverley Jane,
Deakin University, Geelong
Monash University

Technology education provides children with opportunities to be creative as they engage in problem solving and make products that address human needs. When thinking creatively, children generate new ideas through remote associations and brainstorming and this type of thinking is enhanced when attention is allowed to wander in a relaxed and uncompetitive environment. Research shows that the two mental states (generative and nongenerative/analytical) cannot exist simultaneously (Howard-Jones 2002). It follows that at some point in the technological process a child’s generative mental state needs to give way to a nongenerative, analytical state so that the child can focus on analysing information. This research project aims to investigate the impact of analytical thinking on creativity in the context of technology education in young children.

Introduction

Whilst many schools include technology education as part of their curricula, it is reasonable to state that few teachers would have accessed the information relating to the enhancement of creativity and acted on it. There is opportunity to explore the situations in classrooms related to the way that technology education is taught and whether teachers can actively promote the two mental states as the need arises.

Usually, technology education is taught using a process in which the generative thinking state is activated in the design stage of the process. As children move into the evaluation of their technology product, they focus on analytical and critical thinking. However, as the technology process is cyclic, and modification is a suggested stage of the procedure, the children need to be able to move back into the generative mental state so as to make adjustments to their original design in light of new information. We want to know what teachers can do during the teaching sessions to ensure that analytical thinking does not hinder creativity during the cycle back to the investigation and design phases.

This project investigated the teaching of technology at three different schools across the state of Victoria: one metropolitan school (Melbourne), one regional school (Geelong area) and one semi-rural school (Mornington Peninsula). Two teachers (at year three or four level) from each school were invited to participate in the research. However, more teachers participated so that more children could be involved in the technological activity. The teacher’s role was to teach a technology unit across at least four lessons and collect material from the children that would form the basis of our data. Each teacher was provided with an information document that explained the purpose of the study, the roles of the personnel involved in the study and the structure to the lesson plans. The same design brief was used in all three schools and asked the children to:

“Design and make a model of a small recycling device for the home or garden. Your product should be made mainly from recycled materials.”
The children were asked to maintain a record of drawings, ideas, sources of ideas and reflections in a process journal entitled *My Thinking and Ideas Book*. At the end of the unit these books were collected, photocopied and analysed.

The research, in the first instance, is a descriptive account of the structure, content and approaches that teachers put into place in the program. The student booklets could then be related to the teachers’ comments to ascertain if children were able to change their mental states as needed. There are several themes and issues that could be explored further, however, that is outside the scope of this paper. In this paper we address the question: What can teachers do during the teaching sessions to ensure that analytical thinking does not hinder creativity during investigation and design phases?

**Research Questions**

Specifically, the two research questions addressed are:
- What did the teachers do, in respect to incubation, to foster creativity?
- What did the teachers do to foster analytical thinking?

**Literature Review**

In undertaking the research, we are cognisant of recent literature dealing with aspects of creativity and more generally technology education. Creativity in this context is accepted to mean the generation of innovative ideas for the construction of original products containing: new concepts, new methods of arranging materials and new systems (Cropley and Urban, 2000; Howard-Jones, 2002; Kimbell et al, 1996; Westberg, 1990). Cropley and Cropley (2000) discuss creativity in general terms relating it to the cognitive process. Creative problem solving is essential to technology education and can be observed in terms of four phases: preparation, incubation, illumination and insight (Wallas, 1926 in Howard-Jones, 2002). The suggestion is that there may be a need to include a time of ‘non-thinking’ during the incubation of ideas for the production of innovative responses. The period of incubation is considered to be a time when inappropriate responses can be forgotten, allowing more relevant responses to be made available for problem solving (Smith & Blankenship, 1991), but the length of the break appears to make no difference (Eliaz, 2004). The assessment of creative ideas relates directly to work of Feldhusen (1995) and Westberg (1990).

**Dual model of creative cognition (Howard-Jones 2002)**

<table>
<thead>
<tr>
<th>Generative</th>
<th>Nongenerative/analytical</th>
</tr>
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<tbody>
<tr>
<td>Attention: unfocused</td>
<td>Attention: focused</td>
</tr>
<tr>
<td>Generative activity, associative thinking</td>
<td>Nongenerative, analytical, critical thinking</td>
</tr>
<tr>
<td>Primary process thinking</td>
<td>Secondary process thinking</td>
</tr>
<tr>
<td>Less conscious</td>
<td>More conscious</td>
</tr>
<tr>
<td>Hindered by reward, competition</td>
<td>Benefits from reward, competition, evaluation</td>
</tr>
<tr>
<td>Benefits from changes in context</td>
<td>Adversely influenced by distraction</td>
</tr>
<tr>
<td>Relaxation perceived as beneficial</td>
<td>Relaxation not particularly beneficial</td>
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<tr>
<td>Chiefly intrinsically motivated</td>
<td>Can also be extrinsically motivated</td>
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In the present study a technology process is presented as that described in the curriculum documents of Victoria – the Curriculum and Standards Frameworks II (Board of Studies, 2000). Some changes to these models have been suggested in research work of Williams (2000), Fleer (1999), Mawson (2003) and most recently Fleer and Jane (2004).

**Methods-in-practice**

There were two main forms of data: interviews with the teachers concerned and the written work within the student booklets. The interviews with the teachers were informal, but semi–structured, in that the teachers were supplied with several questions beforehand to focus the discussion. Whilst these had the effect of allowing us to come back to areas of interest, the teachers were also given enough freedom to be able to articulate their own thoughts which were unrelated to our questions. These interviews were audio-taped and the tapes were transcribed. For this paper, the transcripts were analysed for any discussion relating to the teachers’ awareness of the four phases of creative problem solving: preparation, incubation, illumination and insight.

The students’ books were collected, photocopied and returned to them. The copies were analysed to develop a number of interpretive accounts in relation to: the generation of new or different solutions in technology education as a function of creative thinking; teaching specifically to enhance one mental state over another (generative versus analytical); sketching as a form of capturing ideas and assessment of creative thinking or analytical thinking outcomes. At this stage discussion of the students’ thinking books is beyond the scope of this paper and will be reported on subsequently.

**Findings and discussion**

**Case Study One**

Case Study One occurred in a school in one of Melbourne’s eastern metropolitan suburbs. The school is a coeducational, government, primary school surrounded by parkland and sports fields. The school possesses an environmental area where the children are able to participate in activities involving gardening, soil regeneration and recycling of plant matter and food scraps. The investigation was conducted with 119 children in five composite grades at Years 3 and 4. The five classroom teachers were experienced in technology education and implemented the task at about the same time during the term. Prior to the task, the children were asked to collect suitable materials that could be used in the constructions of their recycling devices.

All teachers provided responses to the way they conducted the technology task and to their observations. However, because of limited space, only the level coordinator’s observations will be elaborated on here. Mary (pseudonym) introduced the topic to the children by relating the activity to the school’s environmental area and the need to recycle products. Mary presented the design brief to the children and led them through a discussion on what items/products are recycled and on some of the devices that are used to recycle products and materials. This was followed by a brainstorming session where the children could consider new, improved or different methods of recycling. Mary found that the children ‘bounced’ ideas off each other and considered this to be particularly useful for those students struggling for ideas. Further discussion occurred about the types of materials that could be used in the construction of a recycling device and how these materials could be arranged. The children made quick sketches of their ideas in their booklets.
Mary allowed a week for incubation, but with hindsight considered this to be too long. Other teachers in the investigation used a weekend and found this to be appropriate. Mary believed that by allowing the children to take ideas home with them was particularly helpful as this enabled them time to discuss ideas with family members and to search through the home and garden to locate further materials. During the next technology session, the children drew their intended products and discussed their ideas with Mary and peers. Mary noted that unexpectedly, some children displayed creative ideas, and in particular two students who she had not observed showing creativity prior to the task had generated very unusual designs.

Mary thought that many of the children generated creative ideas in their initial sketches. However, there were ‘quite a few’ children who needed to change their designs to accommodate functionality. Once the children had realised that they had limited materials and constructional expertise, their drawings began to reflect more achievable outcomes.

Over the next two to three sessions, the children constructed and evaluated their products. The children tested their products for functionality and made a verbal presentation of how they made the recycling device and how it worked. These verbal presentations were thought to be useful as discussions on the devices helped the children to appreciate the different methods to recycle waste. Mary thought that most children in her class remained focused on the product they had designed during the second session although modifications took place regularly to achieve functionality. This is supported by the drawings the children recorded between the second and final sessions suggesting that once the device had been selected there was little attempt to implement a different idea.

Mary considered that some children used materials in unusual ways, which showed original thinking for students of this age. Examples of this occurred when children arranged containers in special ways to simplify the collection of waste materials or set a range of filters in a system to purify water. There were a limited number of new constructional methods implemented by the children and many used sticking tapes to join materials.

There were occasions when direct teaching of skills and knowledge was necessary. These occurred essentially during the design phase to enable the children to develop their understandings of drawings for communication and during the producing phase when safety issues were dealt with and where children needed specific skills in handling tools and equipment appropriately. Direct teacher involvement also took place during the initial brainstorming session. However, the general approach to the sessions was to allow the children to interact with each other and discuss problems as they arose. This informal classroom structure was thought to be successful in that it supported students in the generation of new ideas and provided them with opportunities to observe how their peers solved similar problems.

With five teachers involved in the investigation a diverse but relevant range of observations were made. These included:

- Some children showed original, creative thinking while others ‘copied’ ideas from their peers and then made modifications.
- There were not many new concepts that the children could generate, but there was a diversity of ideas within a particular topic. This was evidenced with the water recycling devices where the concept is a common one, but within water recycling some children produced unusual ways of collecting, purifying and distributing the water.
The teachers thought that the children needed to have an adequate understanding of the topic. Children who possessed a broader knowledge of recycling appeared to be more creative as many devices included multi-stages such as slurry collectors and dryers. Again, it appeared that the children were accessing prior knowledge as they had studied the production of paper earlier in the year (Feldhusen, 1995).

The crowded curriculum may have impacted on the children’s capacity to expand and develop ideas fully. The teachers would have preferred the children to have more time on the task, particularly during the producing phase.

The general consensus amongst all the teachers was that the children ‘loved’ doing the task. The students were motivated and willingly tried to implement their ideas in practical terms.

**Case Study Two**

In a large regional city in Australia, a grade four class in a local primary school has taken an integrated approach to learning, using ‘the environment’ as the overarching theme. The Year 4 combined class of around 50 students is separated from the rest of the school. The physical surroundings support the environmental theme with open-plan classrooms, large covered verandahs, fenced garden areas and significant under-developed environmental areas which are used for worm farms, planting, seed propagation, recycling and composting. A garden shed holds a range of tools, buckets, hoses, nets and other implements used by the class.

Due to its environmental theme being in concert with the task associated with the research, the school and classroom teachers were approached to see if they would be willing to participate. The third term classroom curriculum plan had an emphasis on recycling, so the research task fitted well.

Although the entire class participated in the research task, only one of the teachers was actually involved in the running of the task and in the subsequent interview. Part of the interview was specifically designed around the question of the relationship between the creativity of the students and the incubation period. Whilst the teachers had been given some indication of the nature of the research in terms of some background to the ideas, it would be unfair to assume that they had an in-depth understanding of the focus of the research. That said, some interesting ideas arose from the discussion with the teacher involved.

When asked about the incubation period, the teacher, David (pseudonym) indicated that the students were not enthusiastic about having to wait. “They were frustrated with that because they wanted to get started.” The task had been introduced to them towards the end of one week, and the teacher had allowed several days before commencing the task in practical terms. Apart from the idea of an incubation time, the teacher had wanted them to think about the task, as he believed that “…school isn’t where you have to come up with the answer.” He added that he believed that many of the children changed their ideas because of the incubation period. Though, once they had firmly decided on an idea, he believed that they then did not change their ideas readily. “…once they had set up what they wanted to do, very rarely did they change that idea.” “The kids that changed most were the more practical kinds.” However, the way David was talking about the incubation
period, it was clear that he had a different interpretation of it than research indicates. Research would say that the incubation period is the time between phases of thinking, say between the analytical and creative phase, in which time is allowed for students to move away from the conditions surrounding the analytical thinking so that they are more receptive of creative thinking. The teacher saw it more as a physical time lapse. However, in that time, students would have moved back and forth through analytic and creative phases.

Further discussion revealed that he also saw the time lapse as an opportunity for students to gather various recycled materials from home and the school. “I knew that I wanted them to go and get their equipment, that’s why I did it – so they had the weekend.” Students used the incubation time to firm up their ideas, talk with parents and locate material – more like the preparation phase (Wallas, 1926, in Howard-Jones, 2002) or the investigation phase of the technology process (Board of Studies, 2000). When they actually started the task at school, most were very task oriented. As a class they talked about how they wanted to approach the task and most wanted to make working models, not just static displays. David commented “Conceptually they were looking at practical things”. He did comment on a student whose model was never intended to work and was more about the concepts behind the implement. It was a ‘fire log maker’ and in the journal, the student had drawn a very elaborate flow chart to indicate how the parts all fitted together and had drawn an outline of his model, indicating where everything should fit. The student’s comments in his journal indicated his frustration in not being able to use electricity to make his model work and to make the machines within his model. In contrast, there was a small group of girls who tended to work together, who constructed very similar models of a weed tumbler and as indicated by the teacher “…they did it as a social group”.

In terms of creativity, the teacher commented on several products that he thought were creative. There was a very simple can crusher that consisted of a base and heavy metal hammer with virtually no construction. The teacher admitted that the student could have done more to the model, but he felt that it was quite creative. It was different to any of the others. Another model that the teacher labelled as creative was such because the student had added many well, thought-out modifications. “He actually thought through lots of issues with that worm farm. He has the canopy over it, with different levels”.

In concluding, David’s observations indicated that many students changed their ideas during the incubation period but rarely after that. He noted that the students were highly intrinsically motivated which is conducive to creativity (Howard-Jones, 2002). He also gave the students considerable autonomy over the task which is also considered important in aiding creativity (Cropley, 1997). David commented that the children seemed to ‘fit’ into several groups. The largest group were those who came to the design phase with a sound idea, ready to start construction. Another, much smaller, group continued to peruse texts and the Internet as their ideas were still fluid. Many students chose to modify existing designs and one group worked at an entirely social level. He noted that the incubation period, not something that he normally incorporates into a technology task, seemed to bring most children to a point where they were ready for the design phase.

Case Study Three
The context for this case study is a semi-rural school on the Mornington Peninsula, approximately 60 kilometres south east of Melbourne. Teachers of Year 4 and two composite grades, Year 3/4 and 4/5, worked with the science co-ordinator to implement the design and technology unit. Unlike case study one, not all of these teachers were
experienced at teaching technology education. The timing of the teaching of the unit was appropriate to the task because the 72 children completed their products during the official ‘recycling week’.

The science co-ordinator, Marilyn (pseudonym) described her role in the following way. “I explained the task to the children and was involved with their designs more than construction due to time constraints. I encouraged the teachers by providing resources/ideas for inspiration.” These ideas took the form of A3 pictures of a range of recycling machines, such as a paper recycling machine and a metal recycling machine. One teacher, who had not taught much technology before, displayed these pictures on the wall for the duration of the task. For Marilyn the preparation stage is vital. “At the beginning of the first lesson we had to make the children understand the recycling process and be very clear on the child’s expectations of what they were to do. The teacher had some input to their creative thinking in terms of motivating the children and setting the context. Some children are intrinsically motivated and others are not.”

The teacher of Year 3/4 had a passion for science and was science trained. For homework she had previously set her grade the task of solving a problem that the children had at home, and they had to use their imagination. In class they did work on conveyor belts and pulleys. Whilst a couple of designs included a conveyor belt, most children did not incorporate these ideas into their designs.

Marilyn reported that after her initial introduction of the technology task, the teachers of the grade had the children continue with the construction and fill in their booklets as time permitted. Two of the teachers initially said that the task was too difficult. All were pleasantly surprised at the results. One teacher said that when told to make a working device the children could not relate to the task. When instead she focused on ‘process’ and told them they would make a flow chart, they understood and analytical thinking was encouraged. One teacher discussed how to advertise and commercially produce products. This encouraged children with their designs.

Usually one week was allowed for incubation. However, due to cup weekend one teacher had a two-week incubation period. Marilyn thought that this incubation time was too long. She commented, “Ideally, a few days between sessions would have been enough.” During the incubation period some children did consider new ideas or approaches to their task. She continued “Some children did not appear affected by the time lapse, while some were completely unfocused, even needing to be reminded about what they were recycling!” These findings are in contrast to Eliaz (2004) who found that the length of the break made no difference.

Once the children had commenced the task and were implementing analytical thinking, Marilyn thought they were able to generate new ideas but to a lesser degree. As some children were not satisfied with the result, they came up with totally new ideas. Other children modified their ideas only partially. However, most children did not generate ‘totally’ new ideas. One child decided right at the start of the introductory lesson what he was going to do. He did not modify his ideas much at all, despite information that would have complemented his design.

In Marilyn’s view some basic ideas showed a lot of creativity. Examples include a metal recycling device that collected metal ship scraps from under the ocean; a bubble gum recycling device, a clay-recycling device. It must be noted here that many of the designs, such as the metal ship-recycling device, did not meet the original criterion that the device was to be for recycling in the home or garden. Similar to case study one, there were several
quite complex paper recycling devices produced, that were made by the girls. Some unusual ideas discussed by the children were:

- how to design a device that worked on land and in water;
- how they could become ‘robots’ and be a part of their design;
- how a hydraulic system works and how to incorporate that knowledge into their design.

Marilyn considers the creative stage to be very important. “If the planning was not developed, I felt the construction and analytical stage was compromised. However, some children drew fantastic designs, yet they were not able to transfer these to a working model. Analytical thinking was happening but to a lesser extent.” The teacher’s role is significant as Marilyn identifies below.

Due to the fact that I could compare grades, I noticed that the teacher as a model was significant. One teacher taught the children skills related to how cogs, conveyors belts and pulleys etc. worked. Another teacher taught the children the actual process involved in recycling, rather than leaving the children to rely on their imagination. (Marilyn)

In Marilyn’s view the analytical thinking seemed dependent on the child’s attitude. If the children were prepared to endure and not become frustrated and thus change their plan, deeper thinking occurred and a high level of satisfaction encouraged them further. “I see creative and analytical thinking as independent skills. However, I see that they complement each other and enhance each other if used in an encouraging and supporting context.”

Marilyn suggested ways to get more detailed responses in the children’s thinking and ideas booklets, and felt that the teacher’s role was important here. Although the questions were good she wondered whether they were meaningful for the children. Is there a better way to get the information? She felt that sharing their ideas with the larger group is a good way.

Marilyn invited the researcher into the classrooms during the production phase. During this time comments made by the children were:

- This project is going great.
- I thought it was fun.
- It’s tricky to cooperate and work together.
- I don’t have this type of thing – no big boxes, only small tissue box, which is a little frustrating.

At the end of the unit the researcher revisited the classrooms. The children were keen to present their completed products to the whole grade and to describe verbally how their device worked. In one grade this sharing also involved reading the instructions of how to operate the device so that others could use it. The children in another grade also included a description of an advertisement to market their device. These additional aspects relating to the task, encouraged the children to make links with the literacy area and focus on communication and social aspects associated with their products.

**Conclusion**

This research provided an opportunity for several primary teachers to focus on enhancing creativity in technology education and to explore the notion of the incubation phase of creative problem solving. Although initially, two teachers from three schools were invited to participate, more teachers participated so that more children had the opportunity to be involved in the technological activity. In this paper the focus has been on how the teachers fostered creativity as they implemented the technology unit. In most classrooms
where this technological activity took place, the children were given autonomy of their actions in an informal classroom structure.

Once the children had produced their recycling devices, the teachers were given a series of questions prior to an informal interview. These questions required the teachers to reflect on the incubation phase and think about how it may have affected the creativity of the children’s designs. Interviews revealed that the majority of children rarely changed their ideas substantially after the incubation phase. Some teachers thought that the individual child’s attitude and motivation affected the degree of changes that occurred.

In this study a time frame of only several days appears to be ideal for the incubation phase, and more time may hinder creativity. These findings have implications for teachers of technology who assign the same day and time each week for technology learning. The teachers involved in the study thought that the length of the break for the incubation period did affect the creativity aspect of the designs, which challenges the ideas of Eliaz (2004) who reported that the length of the break makes no difference.

During the incubation phase of several days, children were able to discuss their ideas with family members. As children learn in social and cultural contexts these discussions can be fruitful. The teachers indicated that peer discussions also played an important role after the generation of designs. The general consensus amongst all the teachers involved in the research was that the children ‘loved’ doing the task. There was a real ‘buzz’ in the classrooms, and the children were motivated and willingly tried to implement their ideas in practical terms.

References


