Justification of the Dual-Phase Project-Based Pedagogical Approach in a Primary School Technology Unit

Michael Drain, Victoria University of Wellington, New Zealand

Abstract

This research paper describes the use of the Cognitive Apprenticeship (CA) framework to analyse the practices of teacher and students observed during a technology unit. Twenty three children aged 9-10 years were involved in the research and they were taught in a standard classroom. The analysis provides evidence that a two-phase project-based approach was an effective way to implement a technology unit with this primary school class.

Key words

project based approach, primary technology, cognitive apprenticeship

Introduction

Technology projects have often been recommended as a pedagogical approach for technology education (Hill, 1998; Mioduser & Betzer, 2007). The intention is to provide a technological practice environment in which students can learn technological concepts and processes while developing solutions to meet real needs or opportunities. This approach has been promoted as *project-based learning* (Barlex, 2006) or *problem-based learning* (Williams, 2000).

Project-based learning can place extra demands on a teacher to respond to the needs of individual students as they work on their individual projects. The project-based approach is more manageable when it is provided through a dual-phase plan in which students are taught technological knowledge and skills before they engage in project activities (Good & Jarvenin, 2007). This division of technology units into two phases is made clear in the Nuffield Primary Solutions technology units, which identify a sequence of focused practical tasks, followed by a design and make task (Nuffield Foundation, 2001). The *starting point approach* is designed in a similar way, but with a more open design brief in the project phase. This approach has been found to have the added advantage of "reconciling the conflicting demands of teaching specific skills and knowledge while encouraging individuals to be as creative as possible" (Good & Jarvenin, 2007 p. 99).

Although the dual-phase project-based pedagogical approach has been shown to have benefits in practice, there is a need to justify this approach within a theoretical foundation. This study makes a start towards this by using Cognitive Apprenticeship (CA) as a theoretical reference framework. CA has been proposed as a comprehensive learning environment for technology education (Duncan, 1996; Drain & Compton, 2009). It is based on the traditional concept of apprenticeship, but extends it to whole class teaching and includes cognitive skills and processes in addition to physical ones (Collins, 2006). Apprenticeship can be viewed as an instructional paradigm whereby "a novice gets to be an expert through the mechanism of acculturation into the world of the expert" (Farnham-Higgerty, 1994).

CA arises from situated cognition theory, which asserts that students learn best when they are immersed in real life contexts and engage with authentic problems (Brown, Collins & Duguid, 1989). Students in a situated learning environment have access to a community of practice of peers and experts. In technology education this engagement in practice would enable students to become part of a community of learning where they could access technological knowledge from other practitioners, both within and outside the school, and eventually contribute their own knowledge to the community. This community of learning could be developed with the support of the teacher through the CA model.

The CA framework provides teaching and learning principles arranged into four dimensions: *content, method, sequencing and sociology* (Collins, 2006). These have been designed to ensure that after their introduction to a subject domain, students are supported in their progress through to exploration, competence and independence. Collins explains that "before apprenticeship methods can be applied to learn cognitive skills, the learning environment has to be changed to make these internal thought processes externally visible" (Collins, 2006, p. 48). In technology education many opportunities exist for cognitive processes to be revealed through the on-going development of technological outcomes (Compton & Harwood, 2005; Kimbell et al, 1991).

Little research has been done to relate CA to classroom or workshop practice related to Technology. In the case study described in this paper the CA framework was used to analyse the practices of a teacher and her students after they had completed a technology unit called *Pop-up Books.* The unit enabled the class to gain knowledge about the nature of 'paper engineering', and the

mechanisms of pop-up books, in order that each student could produce a pop-up book for younger children in the school. The technology unit was integrated with an English unit, in order for the children to plan the written and pictorial content to be integrated with the technological design. The teacher planned the technology unit with the following structure (abbreviated):

Pop-up Book Unit
Week 1:
Starter activity – photograph one mechanism each from a pop-up book.
Week 2:
Categorising mechanisms – students sort photos by mechanism type.
Week 3:
Engineers – a talk by neighbourhood engineers
Weeks 4-5:
Modelling – teacher demonstrates how to make pop-up mechanisms, and students practise by making pop-up models.
Week 6:
Video – a book designer shows how he designs pop-up books.
Week 6-7:
Pop-up cards – pupils design a card, make the card, and evaluate it with Plus-Minus-Improve chart.
Week 8:
Planning pop-up book – discuss criteria, draft on storyboards.
Weeks 9-11:
Making pop-up book – mock-up, evaluate, make pages, bind book.

The unit was planned with reference to the New Zealand technology curriculum of 1999-2009 (Ministry of Education, 1995), which promotes a technological practice approach (Compton & France, 2007). The teacher in this study decided that the class should complete a series of teacher-directed lessons before engaging in technological practice projects.

Methodology

This research was a case study of a Year 5 New Zealand primary school class and their teacher during a technology unit. This was a class of twenty seven children aged 9-10 years, of whom twenty three participated in the study. They were taught in a standard general classroom with children's individual desks arranged in seven groups. It also contained three desktop computers, four laptops, and a projector. The class was taught by a general primary teacher (female) with seven years teaching experience in England and New Zealand. A comprehensive photographic and video record of all activities was made throughout the unit. The teacher's whiteboards were photographed, and also the pages of student workbooks and their finished products. Selected photographs were used for semi-structured photo-elicitation interviews with each child and the teacher at the end of the unit (Epstein et al, 2006). The data enabled analysis of the activities using the principles of the CA framework (Collins, 2006). An interpretivist paradigm was used, whereby the researcher combined evidence to interpret the pedagogical methods of each learning activity (Cohen, Manion,& Morrison, 2000).

A qualitative analysis procedure recommended by Lichtman (2006) was employed for coding and categorising the data by interpreting, reviewing and refining, and then developing themes or concepts from it.

Results

The first half of the unit was comprised of activities designed to develop knowledge of technological concepts

UNIT STRUCTURE	
Phases	Stages
Phase 1: Focused Tasks	1. Examining pop-up books 2. Engineers visit 3. Making models from teacher demonstrations 4. Making models from printed instructions 5. Researching a pop-up book designer
Phase 2: Project Tasks	6. Pop-up card 7. Pop-up book 8. Evaluation

Table 1. Unit Structure

and procedures, and the second half was devoted to project-based activities in which children were able to design and make products. This produced a clear division of the unit into two phases comprised of eight stages (Table 1).

The activities observed in the eight stages of the technology unit were analysed using CA principles. In the following paragraphs the activities of the case study class are described and compared with the principles of the CA framework. The headings are the dimensions of CA, under which the principles of CA are numbered.

Content

The content dimension of the CA framework consists of four types of knowledge required for expertise:

1. Domain knowledge is comprised of "subject-matter specific concepts, facts and procedures" (Collins, 2006, p. 50). Other writers have divided such subject knowledge into conceptual and procedural knowledge (McCormick, 1997), but Collins keeps these together as domain knowledge in order to provide scope for a focus on strategic knowledge , i.e. the knowledge of how to make use of these concepts and procedures to solve real-world problems (Collins, 2006).

In the case study, domain knowledge was related to the mechanisms of pop-up books and the real-world issues of designing and producing a commercial product. The activities or tasks that focused on domain knowledge were all concentrated into Phase 1. The teacher provided examples of existing pop-up books to enable the children to photograph them and categorise the variations by making photo charts. Neighbourhood Engineers talked to the class about the importance of consulting with clients, planning in detail and quality control. The children were introduced to the activities of a professional pop-up book maker through the medium of *YouTube* internet videos. Knowledge of functional aspects of pop-up mechanisms was built up through practical modelling activities and the children summarised their knowledge in a technological vocabulary list and a wall display.

2. Heuristic strategies are "generally applicable techniques for accomplishing tasks" (Collins, 2006 p. 49). Collins considers these strategies to be practitioner-devised decisions and actions, such as tacitly acquired tricks of the trade. Many of them are shared from expert to novice or developed through pupils' shared strategies (ibid).

Heuristic strategies were introduced in Phase 1. While demonstrating various techniques for making pop-up mechanisms the teacher talked about the reasons for her actions and shared her personal tips for improving the quality of the results. As she demonstrated the use of tools such as craft knives and guillotine, she explained the techniques she had found best to keep the paper steady and keep her fingers safe from the blades. In Phase 2 the children continued to develop their tacit knowledge of heuristic strategies as needed. Children were observed developing techniques for specific purposes, often sharing them with classmates. For example, a child used a digital camera to produce a printed enlargement of her drawing and taught the technique to another child.

3. Control strategies are "general approaches for directing one's solution process" (Collins, 2006 p. 49). These require pupils to set goals, plan ahead, and monitor the progress being made or difficulties encountered. This might include reference to other aspects of the cognitive apprenticeship framework to find solutions (ibid).

The use of control strategies by children was not evident in Phase 1. This phase provided few opportunities for children to make planning decisions. However in Phase 2 the children were introduced to a simple design process of plan-design-model-evaluate-make. They used the process to produce a pop-up card and their success with this encouraged them to apply the process to a 6-page pop-up book. In their journals the children wrote down their intentions for problem-solving:

> *I am planning what I can do with my pop-up book and also I have a few mistakes with the pop-ups. My goal is to practise until I get it right.*

4. Learning strategies involve "knowledge about how to learn new concepts, facts and procedures" (Collins, 2006 p. 49). This approach encourages pupils to think about their learning needs and difficulties.

The focus on learning strategies was stronger in Phase 1. The teacher provided a variety of different approaches to learning, such as technological vocabulary-building, printed instructions, and practical activities. Different children reported different preferences for learning strategies. For example, when asked about their preferences for learning from text instructions or pictures, children gave varied responses:

> – *The pictures – the words kind of confused me.*
> – *Probably the words.*
> – *All of it was really useful.*

Method

This dimension of the CA framework contains six teaching and learning methods. They provide opportunities for

RESEARCH

observation, practising skills, and developing independence.

1. Modelling by the teacher provides opportunities for students to observe demonstrations of expert practices (Collins, 2006). Collins recommends that the teacher should externalise any internal processes, such as decision-making, by discussing the related intentions and options (ibid). This approach requires that the teacher has good abilities in the relevant domain, especially when modelling problem-solving procedures with an authentic new problem rather than a prepared one.

In Phase 1 the pupils observed the teacher demonstrating many of her techniques for making pop-up book mechanisms, and immediately followed by making the same mechanism themselves. The teacher always practiced the mechanisms before demonstrating them. However, on some occasions she needed to redesign a model and called on the class to help her, which allowed the children to guide the demonstration.

2. Coaching consists of observing a student during a task, and providing formative feedback such as hints, reminders and challenges to help the student improve (Collins, 2006).

In both phases the teacher visited students or groups at their desks, examined their work in progress and discussed successes, problems and solutions with them. Each pupil was given individual coaching on the safe use of a craft knife and guillotine. The teacher also viewed each student's paper mock-up of their pop-up book and discussed it with them.

3. Scaffolding refers to supports provided for the students to assist learning. These can be simple suggestions, or can be physical supports such as templates or worksheets. The purpose is to provide temporary support that is gradually removed until students can work independently (Collins, 2006).

Scaffolding was found in both phases of the unit. The teacher in the case study provided clear learning intentions for each activity, and helped the pupils to determine suitable success criteria. She provided templates for some activities, such as for evaluating their mock-ups, products and processes.

4. Articulation involves "getting students to explicitly state their knowledge, reasoning or problem-solving processes" (Collins, 2006 p. 51). It often occurs when students respond to questioning, such as during coaching or class discussions, but can also be encouraged by co-operative group activities.

Articulation was observed in both phases of the unit. In Phase 1 the children shared their problems and solutions for making card mechanisms in class debriefing sessions. They also formed into 'expert groups' to develop collaborative multi-mechanism pop-up page designs, and presented their 3D mock-up models to the class. In Phase 2 their articulation of progress and problems was focused by completing journals and evaluations.

5. Reflection in CA involves students considering their own problem-solving processes in comparison with expert practice, other students' solutions, or "an internal cognitive model of expertise" (Collins, 2006 p. 51).

In Phase 1 the children evaluated their work and identified problems. During their main Phase 2 project of designing and making a pop-up book they were asked to write a journal. Most entries were simple records of the day's activities, but some reflective comments were found, such as:

> *I had to start my storyboard again. I made it nicer than my first plan because I put more things into it.*

6. Exploration involves "guiding students to a mode of problem-solving on their own" (Collins, 2006, p. 51). It encourages them to "pose and solve their own problems" (Collins, 2006, p. 49).

In Phase 1 the teacher set exploratory tasks to introduce the pupils to independent trialling of mechanism ideas by making paper pop-up models. The pupils continued in this mode in Phase 2 when making paper mock-ups for their pop-up book project designs and developing them further.

Sequencing

Three principles are recommended for planning the order of learning activities:

1. Increasing complexity involves providing a sequence of activities in which skills are able to develop with increasing expertise (Collins, 2006). Tasks are designed by the teacher to be appropriate for the initial needs of the pupils while providing challenges to encourage progression.

In Phase 1 the children practised with simple mechanisms at first and then moved to more complex mechanisms. Also, the teacher provided some challenging mechanisms for extension activities. She found that it was difficult to choose which practical activities to introduce to the class, due to the range of abilities in the class. Some activities

produced outcomes ranging from non-functional to innovative. Children often needed more than one attempt to succeed but some children continued developing the complexity of their mechanisms in their Phase 2 projects.

2. Increasing diversity means providing "a sequence of tasks in which a wider and wider variety of strategies and skills are required" (Collins, 2006, p. 52). It also allows for richer contexts and application to more diverse problems.

In Phase 1 the children began by replicating mechanisms from their teacher's demonstrations, while later activities allowed them to become more independent. Many of them produced outcomes that became more innovative and diverse. During the Phase 2 project work most children restricted their mechanisms to a selection of two or three types but some diversity was found in the ways they were used.

3. Global before local skills means "having a clear conceptual model of the overall activity" (Collins, 2006, p. 52). This enables students to plan ahead and then proceed by adding detail to the concept.

The project work in Phase 2 provided on-going opportunities to use the *global to local skills* principle. The pupils planned their pop-up book as written ideas and then as a drawing before making a mock-up and a finished card. They used a storyboard to plan their pop-up books holistically before committing to developing their working mechanisms page by page as a mock-up.

Sociology

Collins (2006) recommends four principles to enhance the social environment for learning:

1. Situated learning involves having students "carry out tasks and solve problems in an environment that reflects the nature of such tasks in the world" (Collins, 2006, p. 52). Students are more engaged and motivated when learning has an authentic purpose (Turnbull, 2002).

In the Phase 2 projects the children designed and made real products. The first project involved producing a pop-up card for a friend, and the second project involved producing a pop-up book for their buddy class (younger children). This gave them a purpose for each project, and also a purpose for investigating related products and professions in the real world.

2. A community of practice is a learning environment in which "the participants actively communicate about and engage in the skills involved in expertise" (Collins, 2006, p. 52). It typically involves mutual dependency and shared experiences (ibid).

The children in the case study were given opportunities to share their problems and solutions with the class. The expert groups that had made presentations in Phase 1 about their experiences with a mechanism were sometimes consulted by other class members in Phase 2, as reported in their journals:

> *It was hard doing the floating layers. I am going to get an expert on floating layers to help me.*
>
> *I had one problem but I worked it through. Asked an expert. It was B. She told me how to make a sliding mechanism.*

3. Intrinsic motivation is a result of student interest in the topic and the learning goals. Collins has found that this is enhanced in situated learning, and that a community of practice can provide support (Collins, 2006).

In Phase 1 intrinsic motivation was inspired by novel activities like analysing real pop-up books and meeting real engineers. In Phase 2 the children showed intrinsic motivation by working independently with high levels of commitment for eight sessions during the main project task (producing a pop-up book).

4. Co-operation refers to children working together on problem-solving (Collins, 2006).

In Phase 1 the case study children worked together in co-operative groups. One activity involved expert groups of children with interest in the same mechanism. When working on their independent projects the children shared ideas with their home group members. The highest quality outcomes were concentrated in one particularly co-operative group.

Findings

The analysis of the activities described above has been summarised as a matrix in Appendix 1. This matrix confirms the widespread use of CA principles throughout this technology unit. None of the principles was in continuous use but all had a major or supporting role at various stages of the unit.

The data in the Appendix 1 matrix has been consolidated to produce a histogram, shown in Appendix 2. This histogram shows that many aspects of the two phases are complementary, with each phase providing opportunities for CA principles that are weak or absent in the other.

Justification of the Dual-Phase Project-Based Pedagogical Approach in a Primary School Technology Unit

The clearest examples of this are:

The development of *domain knowledge* was a strong focus in Phase 1 but not in Phase 2 (Appendix 2). This seems to have been due to a change of focus in Phase 2 to *heuristic strategies* in a *situated learning* scenario employing the domain knowledge learned in Phase 1 (see Appendix 1).

Control strategies and *Global to local skills* were clearly present in the design process of Phase 2 but absent from Phase 1 due to the teacher-designed nature of the Phase 1 activities (Appendix 2).

Situated learning was experienced during technological practice projects of Phase 2 but absent from Phase 1 due to the clear focus on practising procedural skills in that phase (Appendix 2).

It can be seen that, in this case study, neither of the phases was able to provide the complete range of CA principles on its own. However, as a combination they ensured that the pupils were given opportunities to engage with all the principles of the CA framework. This can be seen as justification for the two-phase design of this technology unit.

The teacher of the case study unit did not plan the unit with CA principles in mind. However, CA is a framework that combines principles from many sources and it seems that the teacher has reached similar conclusions from her own teaching experience and from her repertoire of teaching and learning strategies.

Conclusion

This study has provided evidence that a two-phase teaching approach was able to be employed successfully in a primary school technology unit. The two-phase approach enabled the teacher to provide support for development of knowledge and skills to a level where the students became sufficiently competent to complete independent technological practice projects. The justification through theory is that it enabled the principles of the Cognitive Apprenticeship framework to be achieved through the implementation of two phases that were complementary.

Implications

Primary teachers often lack confidence in their technological content expertise (Jones & Moreland, 2004), but this study shows that it was possible for a teacher to effectively make use of her existing range of teaching strategies for the design of a technology unit and develop sufficient expertise to be able to demonstrate relevant technological procedures at a primary school level.

Although CA was used as an analysis tool in this study, the results suggest that it would also be effective as a planning tool, especially when preparing to use a dual-phase project-based approach for a technology unit. Further research is needed to examine this promising combination.

References

Barlex, D. (2006). Pedagogy to promote reflection and understanding in school technology courses. In J. R. Dakers (Ed.), *Defining Technological Literacy - Towards an epistemological framework.* New York: Palgrave MacMillan.

Brown, J. S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher,* 18(1), 32-42.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education.* London: RoutledgeFalmer.

Collins, A. (2006). Cognitive apprenticeship. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 47-60). Cambridge: Cambridge University Press.

Compton, V. J., & France, B. (2007). Towards a new technological literacy: curriculum development with a difference. *Curriculum Matters,* 3(2). 158-176.

Compton, V. & Harwood, C. (2005). Progression in technology education in New Zealand: components of practice as a way forward. *International Journal of Technology and Design Education,* 15 (3), 253-287.

Drain, M. & Compton, V. (2009). Cognitive apprenticeship as a pedagogical framework for technology education. *Proceedings of the Seventh International Primary Design and Technology Conference,* CRIPT, Birmingham City University, England, June 2009, 49-55.

Duncan, S. L. S. (1996). Cognitive apprenticeship in classroom instruction: implications for industrial and technical teacher education. *Journal of Industrial Teacher Education,* 33(2), 1-18.

Epstein, I., Stevens, B., McKeever, P. & Baruchel, S. (2006). Photo elicitation interview (PEI): Using photos to elicit children's perspectives. *International Journal of Qualitative Methods,* 5(3), 1-9.

RESEARCH

Farnham-Higgerty, S. (1994). Paradigms of knowledge and instruction. *Review of Educational Research,* 64(3), 463-477.

Good, K., & Jarvenin, E. (2007). An examination of the starting point approach to design and technology. *Journal of Technology Studies,* 33(2), 99-107.

Hill, A. M. (1998). Problem-solving in real life contexts: An alternative for design in technology education. *International Journal of Technology and Design Education,* 8(2), 203-220.

Jones, A., & Moreland, J. (2004). Enhancing practising primary teachers' pedagogical content knowledge in technology. *International Journal of Technology and Design Education,* 14(2), 121-140.

Kimbell, R., Stables, K., Wheeler, T., Wosniak, A. & Kelly, V. (1991). *The Assessment of Performance in Design and Technology.* London: SEAC.

Lichtman, M. (2006). *Qualitative Research in Education: A user's guide.* Thousand Oaks, CA: Sage.

McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education,* 7(2), 141-159.

Ministry of Education (1995). *Technology in the New Zealand Curriculum.* Wellington: Learning Media.

Nuffield Foundation (2001). *Primary Solutions.* www.primarydandt.org/resources: retrieved 10 Oct 2009.

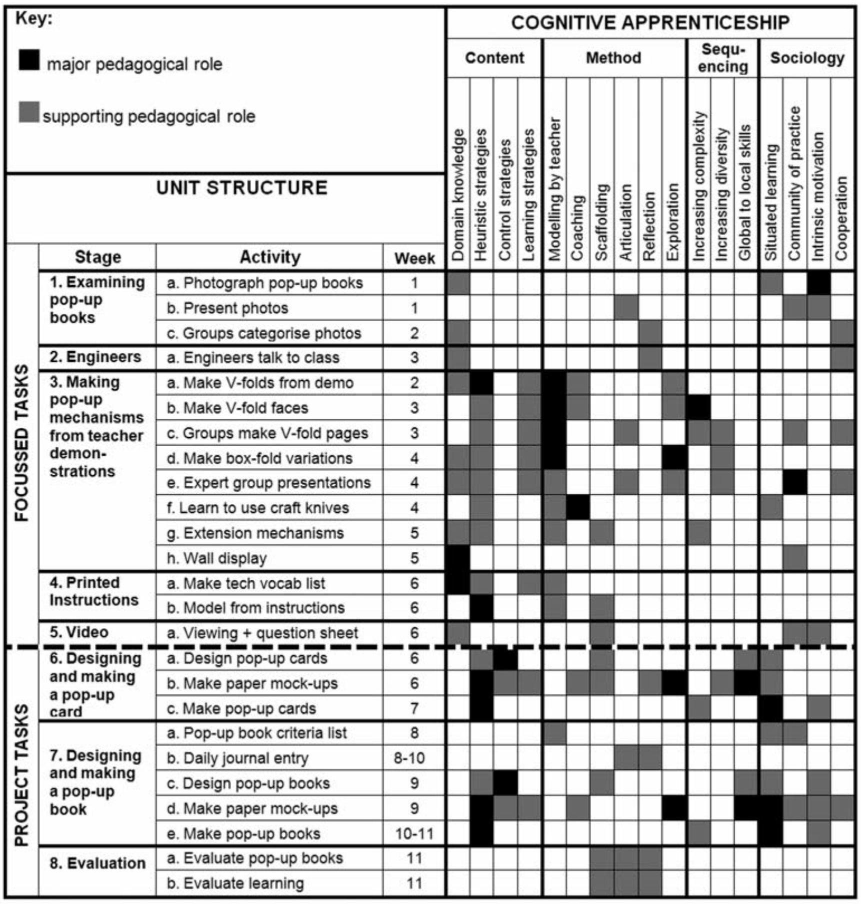
Mioduser, D. & Betzer, N. (2007). The contribution of project-based-learning to high-achievers aquisition of technological knowledge and skills. *International Journal of Technology and Design Education,* 18(1), 59-77.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education,* 12(1), 23-40.

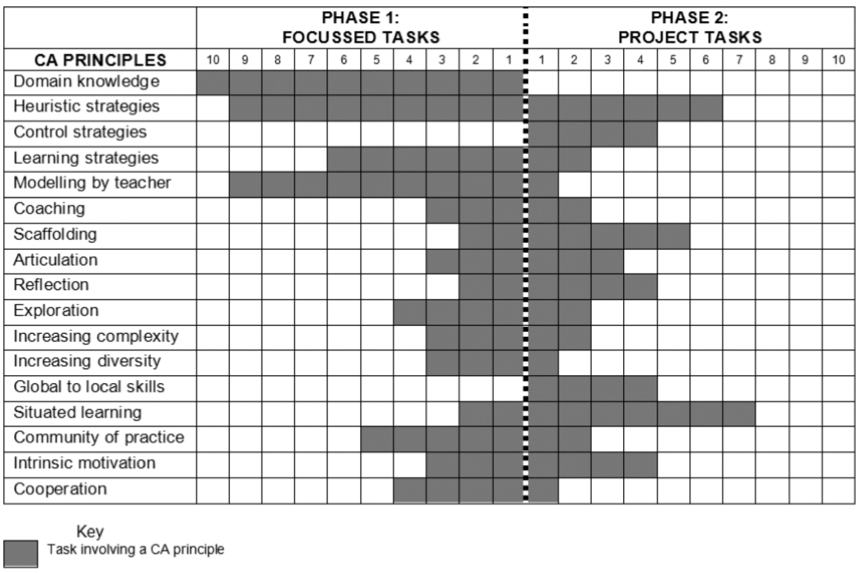
Williams, P. J. (2000). Design: the only methodology of technology? *Journal of Technology Education,* 11(2), 48-60.

michael.drain@vuw.ac.nz

RESEARCH



Appendix 1. CA Analysis of Activities in a Technology Unit



Appendix 2. CA Analysis of Phases in a Technology Unit