Connecting Authentic Innovation Activities to the Design Process

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Although history is full of inventors and innovations, principles underpinning the design (or innovation) process were only first described in the 1960's and 1970's. Beckman and Barry (2007) connect the design process to learning by experience, a process linked to experiential learning, and a forerunner of authentic learning. This study concerns an authentic innovation project, in which 13 groups of upper secondary school students (aged 16–17 years) solved real-world problems of their choice. The five-week innovation project offered students possibilities to think, design, discuss and reflect. The specific aim of this study is to present and analyse the activities that took place at different stages of the innovation/design process by posing the following research question: Do the students taking part in the innovation project engage one or more phases of the design process? Our results suggest that students with little or no previous experience of innovating or designing, not only solve the tasks they set out to solve, but also do so in a manner that mimics the way a trained inventor might work. These observations are closely associated with the learning models described by Beckman and Barry, and have implications for the teaching of design and innovation processes.

Key Words: Authentic learning, Innovation project, Upper secondary school, Design process.

1. INTRODUCTION

"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (The Organisation for Economic Co-operation and Development [OECD], 2005, p. 46). To be able to perform such an implementation and thus produce an innovation, creativity is necessary, and "design is what links creativity and innovation" (Cox, 2005, p. 2). Problem solving and design are ubiquitous in technology education research. However, there have been few attempts to link the design process with concrete authentic innovation programmes (Mioduser, 2009; Schooner, Nordlöf, Klasander, & Hallström, 2017; Williams, 2000). As part of a 2016 innovation project at a Swedish upper secondary school, students worked in groups to solve real-world problems of their own choice. The specific aim of the current study is to present and analyse the activities that took place at different stages of the subsequent innovation/design process by posing the following research question: Do students participating in the innovation project engage one or more phases of the design process?

2. THE INNOVATION / DESIGN PROCESS

Humans invent things to improve their daily life. We know of stone tools dating from 2.6 million years ago, but there could be even older artefacts dating back 3.3 million years (Domínguez-Rodrigo & Alcalá, 2016). Anthropologists are also of the view that humans co-evolved with the tools that they produced (e.g. Stiegler, 1998). But, exactly how the shape or function of tools were decided upon, in terms of being operationalized as a design process *per se*, was only first described in the 1960's and 1970's through the pioneering work of

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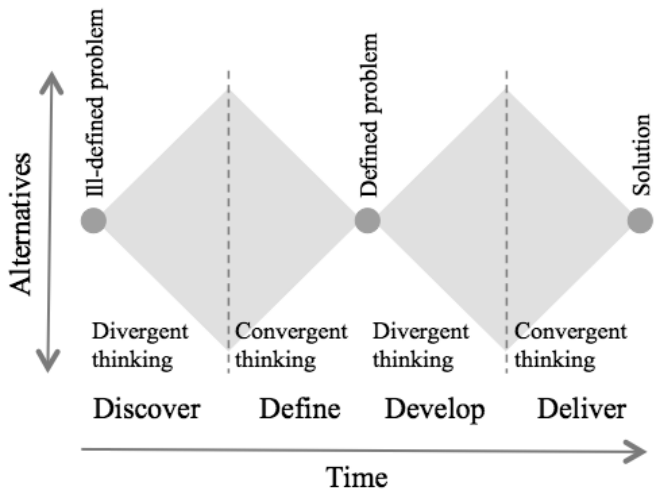
scholars such as Herbert Simon, John Christopher Jones, Bruce Archer, Gerhard Pahl and Wolfgang Beitz (Bayazit, 2004; Pahl, Frankenberger & Badke-Schaub, 1999).

According to Simon (1996), innovation activities are really about design, and that "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (1996, p. 111). There is no one model to represent the design process. Depending on area of application and tasks, designers tend to use different models. In general, they start with an ill-defined problem and diverge to reveal different aspects of the problem. This is followed by converging toward a single, defined problem. The defined problem is then treated in a similar way to find the solution – divergence to find different possible solutions and convergence to decide on the most favourable (see Fig. 1). This method was introduced in 2005 by the Design Council in the form of the *Double-Diamond* model of design (Design Council, n.d.). Each of these phases encompasses a cyclical process where observations lead to ideas, which in turn, lead to prototypes, followed by testing and subsequent observations, and so forth. An iterative spiral is pursued until a desired outcome is reached (Fig. 2) (Norman, 2013).



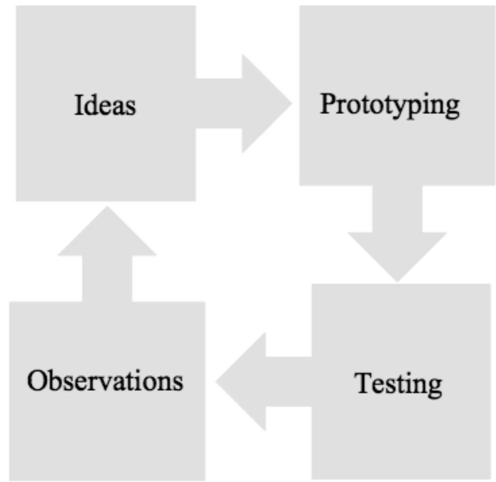


Figure 1 (left). The double-diamond model of design (Modified from the Design Council, 2005, and Norman, 2013).

Figure 2 (right). The iterative spiral (Modified from Norman, 2013).

Even if there are a number of different ways to describe the design process, they all share one common feature in that they comprise of distinct elements and phases (Beckman & Barry, 2007; Norman, 2013; Owen, 1993a; Pahl & Baitz, 1996).

In describing the connection between design and innovation, Owen (1993b) stated that, "design is the creation process through which we employ tools and language to invent artefacts and institutions" (p.2). In line with Cox's earlier assertion that design is what connects creativity and innovation, Owen suggests that there is an innovation process that fits all areas of application even though tools and techniques, as well as theory versus practice, may differ (Cox, 2005; Owen, 1993b).

3. AN INNOVATION PROJECT IN TECHNOLOGY TEACHING

It is obligatory for all students in the upper secondary Technology program in Sweden to participate in the Teknik 1 (Technology 1) course. Teknik 1 contains elements such as problem solving, design, materials and material processing, basic drawing, modelling and CAD techniques. The innovation project in focus in this study was implemented at a Swedish upper secondary school (Svärd, Schönborn, & Hallström, 2017) and consists of a five-week period in which students solve real-life problems in groups. The problems should be pertinent to students' lives and be associated with non-trivial solutions. From a student point of view, one major challenge to overcome is realising that there are no specific instructions provided for the task and teachers only offer scaffolding support. Therefore, the students have to plan and carry out their own projects, including searching for necessary information in areas such as materials, manufacturing and markets, as well as making various financial estimations. They are also requested to develop models, or in some cases, fully operational prototypes of their inventions. For digital solutions, pictures of the modelled interface are expected. This period ends with an exhibition where the students present their results and explain the functions to fellow peers, interested observers, as well as invited professional inventors. The groups receive substantial feedback from the inventors about all aspects of the process.

When students have to take responsibility for their own learning, as in the described innovation project, they typically enter unknown territory. Schooling today often emphasises tasks that are intended to be solved in one particular way (Blumenfeld, Soloway, Marx, Krojcik, Gazdial, & Palinvar, 1991; Blumenfeld, Marx, Soloway, & Krajcik, 1996; Newmann, Bryk, & Nagoka, 2001). Observations in the classroom support this when students continuously ask if they are performing the task in the correct manner, and how the teacher intends grading their work. In the innovation project, it eventually becomes apparent to the students that there are no "right" or "wrong" solutions since the students themselves create and perform the task. The teacher offers nothing more than scaffolding help such as being present, listening to students' thoughts, and offering advice when asked. This could potentially offer the students an optimal learning environment, since "people grow best where they continuously experience an ingenious blend of challenge and support" (Kegan, 1994, p. 42).

The iterative spiral of the innovation process (Fig. 2) shares a relationship with Kolb's Experiential Learning Theory (ELT) since it contains both problem solving and interplay with the environment (Svärd, Schönborn & Hallström, 2017). In this respect, Kolb and Kolb (2013) has stated:

> For a learner to engage fully in the learning cycle, a space must be provided to engage in the four modes of the cycle—feeling, reflection, thinking, and action. It needs to be a hospitable, welcoming space that is characterized by respect for all. It needs to be safe and supportive, but also challenging. It must allow learners to be in charge of their own learning and allow time for the repetitive practice that develops expertise. (p. 20)

Ideally, each group of students should be composed in such a way that they are different in their approaches of perceiving and transforming information. For example, some students prefer abstract conceptualizations and reflection, while others prefer learning by doing (Kayes, Kayes & Kolb, 2005). The groups should not remain in either the concrete or abstract realms, but move freely between them during the iterative innovation process. One way of describing this flux has been suggested by Kolb and Kolb, and others (see Fig. 3). The students do not need to follow the steps in the order as described in Fig. 3, nor do they have to spend equal time within each represented quadrant (Kolb & Kolb, 2013).

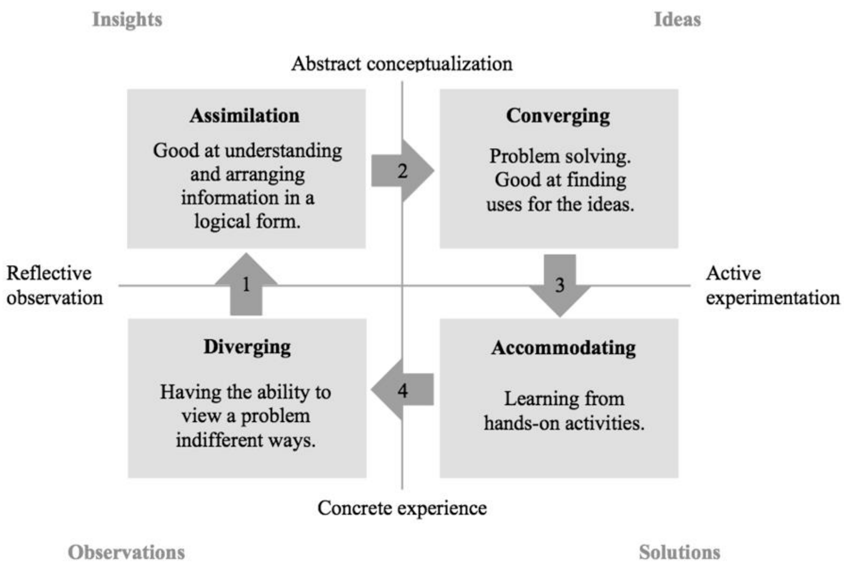


Figure 3. The innovation process as a learning model based on Kolb's learning style inventory. Processes designated by arrows consist of: 1. Problem finding, 2. Problem selecting, 3. Solution finding, and 4. Solution selecting. (Modified from Kolb & Kolb, 2013; Owen, 1993a; Beckman & Barry, 2007).

There are advantages and disadvantages of using this method. Scholars such as Gardner, in his "Multiple intelligences" theory, and Kolb's "Learning style inventory" have presented theoretical frameworks based on the premise that different people learn in different ways. The innovation process as a learning model supports these approaches, since it offers multiple ways to investigate a problem. In contrast, it must also be acknowledged that there are students that are uneasy about unfamiliar learning environments and the possible risks of failing. In this regard, Kolb and Kolb (2013, p. 20) suggests that, "students will often say, 'But I don't have any experience' meaning that they do not believe their experience is of any value to the teacher or for learning the matter at hand". In these cases, one can remind students about Elon Musk's utterance in an interview for *Fast Company*: "There's a silly notion that failure's not an option at NASA. Failure is an option here [at SpaceX, authors comment]. If things are not failing, you are not innovating enough" (Reingold, 2005).

4. METHOD

This study investigates the activities during the main, five-week phase of the innovation project. Data was collected in the form of responses to a series of written questionnaires administered at the end of each of nine lessons included in the innovation project. The questionnaire was answered once per group, wherein a total of 13 groups, each consisting of three to four students, participated in the project. Three questions were answered by ticking multiple-choice boxes together with the option to provide additional comments about a respective day's work. The same questionnaire was administered every lesson. The questions comprising the questionnaire were as follows (see the Appendix for the complete questionnaire):

1) How do you think you performed today?
2) If you answered *Poor* or *Not so good*, then why?
3) What kind of work did you perform during the lesson?

This paper focuses on student responses to question three above, which concerned the activities performed during each lesson.

Tiwari (2008) has suggested an innovation process consisting of three steps, namely *Conception*, *Implementation* and *Marketing* (Fig. 4). This model represents multiple aspects of the currently explored innovation project. Furthermore, if one subsumes both Abstract Conceptualization components (Insights and Ideas) from Fig. 3 into the Implementation step, then it also represents aspects of the innovation process as a learning model as described by Kolb and Kolb (2013). In this regard, analysis of responses to question three (Activities) involved connecting students' answers to each of the steps described in Fig. 4.

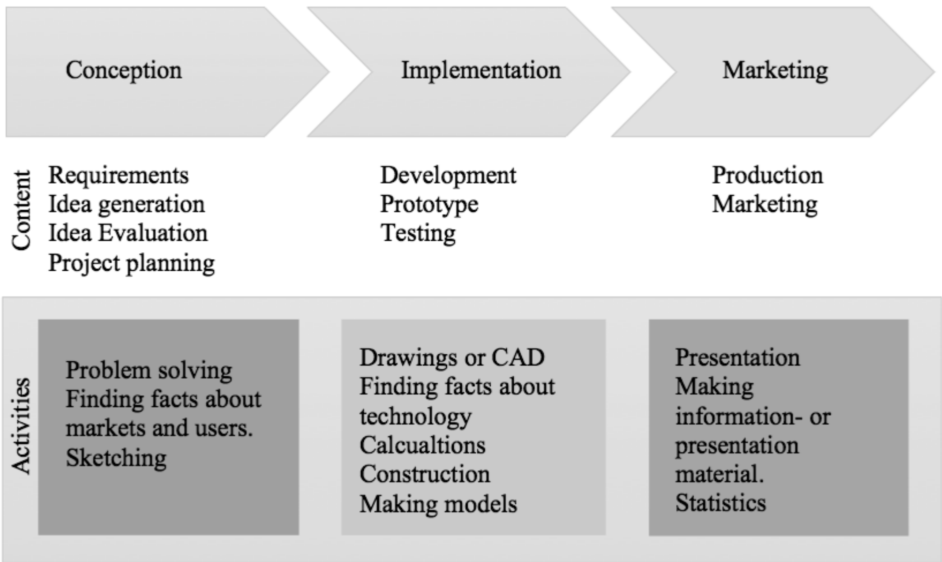


Figure 4. An innovation process suggested by Tiwari (2008) and corresponding activities during lessons as answered by each student group in the questionnaire. Respective colour coding of activities correspond to that used in Fig. 5 (see later).

After each lesson, the selected answers from question three (see Appendix), ”What kind of work did you perform during the lesson?” were sorted into the respective groups of Conception, Implementation and Marketing, as indicated in Fig. 4. If a group selected “Other”, the written specification in the comment was used to designate the categorisation. If “Other” was not followed by a specification, the answer was omitted from analysis. As each student group was able to tick multiple options, a percentage of the answers from the total obtained, after that specific lesson in question, was calculated.

5. RESULTS

The daily activities that emerged from students’ answers during the innovation project are presented in Fig. 5, which illustrates what activities were performed each day. The activities are sorted as per the Conception, Implementation and Marketing categories (cf. Fig. 4).

The results indicate that the Conception category dominated activities during the early initial phase of the innovation project. For the majority of project time, the Implementation phase is the most prevalent, while the Marketing category emerges saliently toward the end of the project. However, Fig. 5 also suggests that the students shuttle back and forth between the activities. For example, although Marketing activities are pronounced at the close of the project, activities related to Conception and Implementation are still being engaged at the same time.

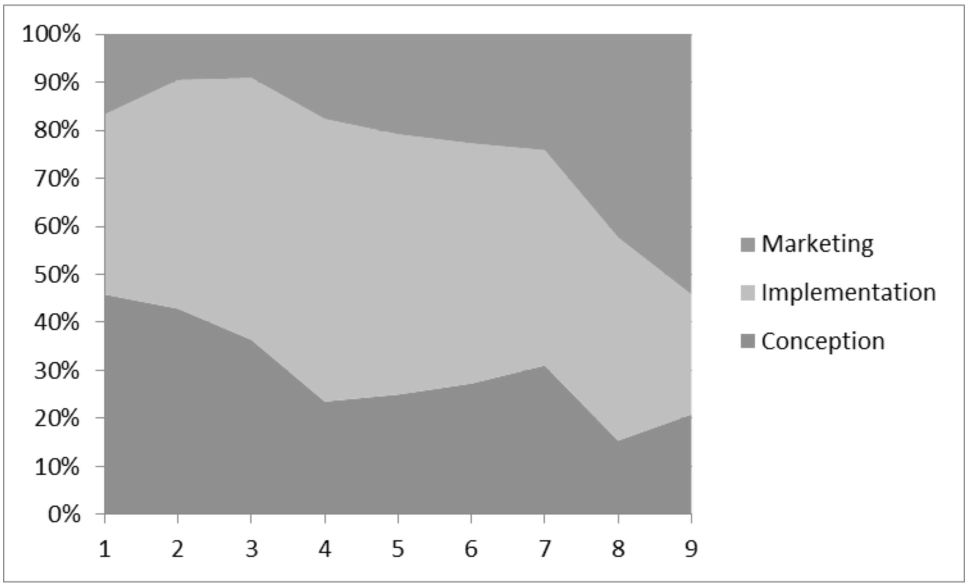


Figure 5. Graph representing the relative score (%) on Marketing, Implementation and Conception activities during the nine lessons of the innovation project in 2016.

6. DISCUSSION AND IMPLICATIONS

If the design process was linear, one might expect the results in Fig. 5 to be directed solely to Conception activities for the first and perhaps second lesson, as the groups chose a problem to solve. During the last lesson, the group’s innovations were presented to other students and invited professional inventors at a school exhibition. In a linear process, this ought to result in the process closing with activities directed to Marketing alone. If the process was indeed linear, the lessons between the start and the end should be mainly Implementation activities. However, as demonstrated in Fig. 5, this is not the case. The presence and relative proportions of activities related to each of Conception, Implementation and Marketing at every single lesson indicate multidirectional and dynamic transitioning between the project phases (cf. Williams, 2000).

As Beckman and Barry (2007) point out, it is expected that a group working on an innovation moves fluidly between the different phases during an iterative process. It is also expected that results arise during the process that change the conditions in such a way that it produces new circumstances for the project, which presents the need to return to an earlier point in the process. This would result in a pattern similar to that revealed in Fig. 5, where groups transition back and forth between scenarios as the project proceeds (Beckman & Barry, 2007).

The result that only 54% of the innovation activities during the exhibition were attributed to Marketing might be unexpected, since the exhibition is really all about presenting the results of the students' efforts. This result could be explained by the feedback the groups receive during the exhibition from fellow students as well as the invited innovators. This feedback induces new solutions as well as other ideas, resulting in exposing innovation activities that were prominent in earlier stages of the innovation process. One should also bear in mind that it is 54% of all activities, not the time spent on each phase. Thus one main finding of this study is that engaging all three innovation components or phases throughout, is conducive to an authentic design process. This also supports the notion that design and innovation are far from static endeavours (cf. de Vries, 2017). Rather, innovation is a dynamic process that relies on constant interplay between the three components, even if there are patterns of their relative salience over time.

Dewey stated that "...nothing takes root in mind when there is no balance between doing and receiving" (1934, p. 45). As suggested by the results of this study, the iterative and cyclical processes during the innovation project transit the groups' activities back and forth between practical and theoretical components; a movement that concerns all four learning modes – experiencing, reflecting, thinking and acting. In turn, Kolb and Kolb's (2013, p. 8) statement that "learning arises from the resolution of creative tension among these four learning modes" underpin the results that have emerged from the research thus far.

The group activities also mimic the type of teamwork that is widely used to develop new products or services nowadays. Furthermore, a group of students consists of different types of learners, a situation that takes advantage of students' diverse ways of learning and approaching a problem (Kayes, Kayes & Kolb, 2005). The outcome of this study raises new questions such as: Does an authentic innovation project improve learning and understanding of design and technology? Will the students show a subsequent increased interest in technology and problem solving? Are potential inventors of the future among these students? Aspects of these questions will be probed during the forthcoming phases of this research programme.

7. REFERENCES

Bayazit, N. (2004). Investigating Design: A Review of Forty Years of Design Research. *Design Issues*, 20(1), 16-29.

Beckman, S., & Barry, M. (2007). Innovation as a Learning Process: Embedding Design Thinking. *California Management Review*. 50(1), 25-56.

Blumenfeld, P., Marx, R., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher, 25*(8), 37-40.

Blumenfeld, P., Soloway, E., Marx, R., Krojcik, J., Gazdial, M., & Palinvar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, *26*(3-4), 369-398.

Cox, G. (2005) *Cox Review of Creativity in Business: building on the UK's strengths*. Retrieved from http://webarchive.nationalarchives.gov.uk/20120704143146/http://www.hm-treasury.gov.uk/d/Cox_review-foreword-definition-terms-exec-summary.pdf

Design Council (n.d.). *A study of the design process*. Retrieved from https://www.designcouncil.org.uk/sites/default/files/asset/document/ElevenLessons_Design_Council%20(2).pdf

de Vries, M. J. (2017). Philosophy as Critique. In P. J. Williams & K. Stables (Eds.), *Critique in Design and Technology Education* (pp. 15-30). Singapore: Springer Nature.

Dewey, J. (1934). *Art as Experience*. New York, NY: Perigee Books.

Domínguez-Rodrigo, M., & Alcalá, L. (2016) 3.3-Million-Year-Old Stone Tools and Butchery Traces? More Evidence Needed. *PaleoAnthropology* 2016, 46-53.

Kayes, A. B., Kayes, D. C., & Kolb, D. A. (2005). Experiential Learning in Teams. *Simulation and Gaming, 36*(3), 1-9.

Kegan, R. (1994). *In Over our Heads: The Mental Demands of Modern Life*. Cambridge, MA: Harvard University Press.

Kolb, A. & Kolb. D. (2013). *The Kolb Learning Style Inventory 4.0: A comprehensive guide to the theory, psychometrics, research on validity and educational applications*. Philadelphia, PA: Hay Group.

Mioduser, D. (2009). Learning technological problem solving: A cognitive/epistemological perspective. In A. Jones & M. J. de Vries (Eds.), *International Handbook of Research and Development in Technology Education*. Rotterdam: Sense Publishers.

Newmann, F., Bryk, A.S., & Nagoka, J.K. (2001). *Authentic intellectual work and standardized tests: Conflict or coexistence? Improving Chicago's schools*. Chicago: Consortium on Chicago School Research.

Norman, D. (2013). *The Design of Everyday Things*. Cambridge, MA: MIT Press
OECD/Eurostat. (2005). *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd ed*. Paris: OECD.
Owen, C. (1993a). Design Research: Building the Knowledge Base. *Design Processes Newsletter, 5/6*
Owen, C. (1993b). Considering Design Fundamentally. *Design Processes Newsletter, 5/3*
Pahl, G., & Beitz, W. (1996). *Engineering Design: A Systematic Approach, 2nd ed*. London: Springer.
Pahl, G., Frankenberger, E., & Badke-Schaub, P. (1999). Historical background and aims of interdisciplinary research between Bamberg, Darmstadt and Munich. *Design Studies, 20*(5), 401-406.
Reingold, J. (2005, February 1). Hondas in Space. Fast Company, 91, Retrieved from https://www.fastcompany.com/52065/hondas-space
Schooner, P., Nordlöf, C., Klasander, C. & Hallström, J. (2017). Design, system, value: The role of problem-solving and critical thinking capabilities in technology education, as perceived by teachers. *Design and Technology Education: an International Journal, 22*(3), 60-75.
Simon, H. (1996). *The Sciences of the Artificial. 3rd ed*. Cambridge, MA: MIT Press.
Stiegler, B. (1998). *Technics and time: The fault of Epimetheus (Vol. 1)*. Palo Alto, CA: Stanford University Press.
Svärd, J., Schönborn, K., & Hallström, J. (2017), Design of an authentic innovation project in Swedish upper secondary technology education in Sweden. *Australasian Journal of Technology Education, 4*, 1-15.
Tiwari, R. (2008). *The Innovation Process*. Retrieved from http://www.global-innovation.net/innovation/index.html
Williams, P. J. (2000). Design: The Only Methodology of Technology? *Journal of Technology Education, 11*(2), 48-60.

APPENDIX

Questionnaire items and possible answers administered after each lesson in the innovation project:

1. How do you think you performed today?

- ☐ Poor
- ☐ Not so good
- ☐ Good
- ☐ Very good

2. If you answered *Poor* or *Not so good*, then why?

- ☐ Disagreement in the group
- ☐ Uninspired
- ☐ Did not know what to do
- ☐ No help from the teacher
- ☐ Someone in the group was missing
- ☐ Other reasons (please specify)

3. What kind of work did you perform during the lesson? (multiple answers possible)

- ☐ Problem solving
- ☐ Drawings or CAD
- ☐ Finding facts about technology (materials, methods, etc.)
- ☐ Finding facts about markets or users
- ☐ Calculations (generally)
- ☐ Construction work
- ☐ Presentation- or information material (making or presenting)
- ☐ Statistics
- ☐ Sketching
- ☐ Making models
- ☐ Other (please specify)