The experience of interacting with technological artefacts

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This article reports on an investigation into the different ways that pupils\textsuperscript{1} interact with technological artefacts. The results are discussed in the context of the need for first-year “introduction to engineering” courses to develop ways to provide students with an environment that facilitates their meaningful interaction with technological artefacts. Fifteen South African pupils, selected to ensure variation with respect to their socio-economic backgrounds, were interviewed after having interacted with a structured technological activity. The interviews were analysed using a phenomenographic approach to obtain an understanding of their interactions with technological artefacts from their perspective. The outcome of the analysis was a set of categories that characterise the key aspects of the different ways in which the interaction was experienced. The findings show that interaction with a technological artefact can be through direction, through instruction, through tinkering, or through engaging.

Keywords: phenomenography, technological literacy, introduction to engineering

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1. Introduction

In the early 1990s, many engineering programmes in the USA began offering project-based first-year ‘introduction to engineering’ courses (cf. Ambrose and Amon 1997, Hoit and Ohland 1998) in response, in part, to the ASEE Engineering Deans Council Pipeline Implementation Committee’s call to ‘develop or expand ... first-year entry programs ... [to] introduce students ... to the spectrum of opportunities in engineering and provide them with engineering experiences’ (Bickart 1991, p.421). The mechanical engineering programme at the University of Cape Town drew on these developments when they introduced their course in 1995 (Sass \textit{et al.} 1997). This course was developed with the aim of introducing students to

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\textsuperscript{1} In this article, people at school are referred to as \textit{pupils} and those at university as \textit{students}.
the real world of engineering by showing how engineers set about doing their work and how they analyse and solve problems. Furthermore, it had the goal of addressing the difficulty some students showed in interacting with technological artefacts through the provision of support to students to help them develop confidence in their interaction.

The course itself consisted, in part, of a number of hands-on projects each with a range of activities. Typically, these projects included the disassembling and reassembling of artefacts such as model aircraft engines, pumps, hydraulic trolley jacks, the building of model aeroplanes, as well as using Lego™ to construct systems allowing the demonstration of concepts such as levers, pulleys and gears. Other activities in the projects included looking at lift and drag characteristics with a wind tunnel, building and then testing amplifiers with an oscilloscope, and a number of spreadsheet-based modelling and optimisation problems. Each of the projects covered in the course had a practical outcome to be achieved by a student in 2½ hours. During the course’s development, no explicit consideration was given to how students would experience interacting with the required technological artefacts in pursuit of these outcomes. It was taken for granted that all students should (after an initial period of acclimatisation to the university experience) be able to make use of the technological artefacts with a similar level of proficiency. However, fourteen years on, it is apparent that this assumption is not appropriate and it has become increasingly evident that many students struggle in various ways to make use of the technological artefacts required for the successful completion of the projects.

This article reports on an investigation into the different ways that pupils interact with technological artefacts. The research grew from a realisation that not all students in a first-year ‘introduction to engineering’ course in Mechanical Engineering were able to interact with the technological artefacts in the course in a meaningful way. Although an attempt had been made to provide a supportive environment for this interaction to take place, anecdotal evidence suggested that many of the students were hesitant to embrace the technological artefacts found in the various project modules. In order to better understand how students in this course might experience this interaction, it was decided to investigate how pupils in their final years of study at school interact with technological artefacts in order to develop a picture of what could be expected of students as they entered the programme.

2. Methodology

Research approach

This research sought to obtain an interpretive understanding of pupil’s interactions with technological artefacts through their eyes – from their experiential perspective. In order to do so, it was necessary to adopt a conceptual framing that had an interpretive understanding as a central focus. A phenomenographic approach (Marton 1981, Marton and Booth 1997) fulfilled this requirement and was used to conduct the study. Central to phenomenography is that it aims to describe the key aspects of the variation of the experience of a phenomenon rather than focus on the richness of individual experiences.
The outcome of a phenomenographic study is a set of categories that characterise the key aspects of the different ways in which an experience can be viewed. Logical relationships between and within categories are found by analysing the structure and the associated meaning underpinning these conceptions. Furthermore, Marton (1994, p.4426) argues that “[t]he different ways of experiencing a certain phenomenon, characterised by corresponding categories of description, represent different capabilities for dealing with (or understanding) that phenomenon”. A critical assumption of phenomenography is that it is possible to characterise variation in the experience of a phenomenon in terms of a limited number of qualitatively different, logically related categories of description (Marton and Booth 1997).

Method

The context of the study is within contemporary South African society. It was assumed that children might have different ways of understanding the world because of the vastly different environments in which they are growing up. Consequently, the pupils who participated in this study were selected to ensure variation with respect to their socio-economic backgrounds. Data were collected from 15 pupils at three schools in Cape Town. The first of these schools was located in an elite suburb, the second was a school servicing an economically depressed suburb, while the third school was located in the heart of a local township where poverty is rife and unemployment levels high.

Pupils were interviewed after they had interacted with a structured activity which had been developed to help ensure that the interview centred on a shared experience of the phenomenon in question. In this way, there was a greater likelihood of ‘establishing a joint definition of what [was] being talked about’ in the interview situation (Säljö 1996, p.23-24). The activity itself consisted of pupils having the opportunity to interact with technological artefacts of increasing complexity. These artefacts were carefully developed to have attributes representative of a range of technological artefacts that the pupils would likely come across in their daily lives. These attributes included both mechanical and electrical aspects as well as elements of computer-based control of their operation.

The multiboard (shown in Figure 1) represents the culmination of the structured activity and allowed pupils the opportunity make a conscious decision about what it was that they wanted to control. This could have been the heater, the light, the buzzer, or any one of the other available devices. A fundamental criterion for developing the structured activity used was that the technological artefacts were all accessible as manifestations of technology in one sense or another.

Before each interview, pupils were given a disposable camera to take home to take a number of photographs of what they perceived to be important representations of what technology meant in their daily lives. These photographs were processed and printed prior to each interview session. The semi-structured interview was firstly centred around their interaction with technological artefacts during the activity followed by further discussion around their experiences of interacting with other technological artefacts. This further discussion of interacting with technological artefacts was largely based around representations of
technology as illustrated in the photographs they had taken. The interviews were transcribed verbatim shortly after completion.

![Figure 1: The multiboard – a technological artefact](image)

During the analysis, from within the collection of extracts, core aspects that made up the ways of experiencing the phenomenon in question were grouped in terms of similar meaning and structure. The extracts were read in the context of all those that had come before and in the context of the interviews from where they had been derived. Each fragment informed and helped to delineate the others. At the same time, themes (Åkerlind 2003, Collier-Reed 2008) that ran through the data were identified and used to structure the logical relationships both within and between the categories as they developed. The analysis alternated between the categories as they are being constituted, the extracts, and the themes looking to substantiate, contradict or revise the relationships that were emerging.

3. Findings

From the analysis of the data, four qualitatively different categories of description emerged. These categories form a logical hierarchy of increasing complexity (from A to D) in terms of the qualitative differences in the ways pupils experience interacting with technological artefacts:

A. Interaction with a technological artefact is through direction.
B. Interaction with a technological artefact is through instruction.
C. Interaction with a technological artefact is through tinkering.
D. Interaction with a technological artefact is through engaging.

In the following sections, the characteristics of each of these categories are described in detail. Extracts from interview transcripts are used to illustrate particular aspects of each category. For each extract used, questions asked by the interviewer are shown in bold and the
responses by the pupil are in regular font. In the responses, what are considered key phrases are italicised. As typical in a phenomenographic study – where categories are made up of extracts from across interviews – illustrative extracts cannot encapsulate the fullness of a category, but rather can only illustrate critical aspects of a category.

**Category A: Interaction with a technological artefact is through direction**

In this category, the experience of interacting with a technological artefact is as the result of a directive by someone. It is not something that happens spontaneously as there is a reluctance to making a first move toward approaching it. This category describes the experience as being on the outside looking in towards a technological artefact as a reified object; the artefact is placed on a ‘pedestal’ in an exalted, unapproachable position.

Interaction takes place in a formalised context where pupils are required to respond to the directions of an authority. They only want to do what they are told and nothing more and this is achieved by following directions exactly. For example:

- **Did you try anything different that wasn’t in [the tutorial]?”**
  No in case I messed up, oh no, thank you.

- **Tell me about messing it up, is that something you worry about when you work with technology?”**
  Sometimes yes.

- **Why?”**
  [B]ecause just now I mess up and the whole thing is broken again and then, no, it’s fine, I don’t want to mess it up cause if I press one thing and it’s wrong and then the whole thing sommer [just] goes wrong.

There is no use of prior experience and there is no recognised purpose derived from this interaction other than making the artefact work within a specific framework as required by the authority figure. The following extract illustrates that even when given free licence to explore an artefact as they saw fit, the fear of possibly making a mistake – not necessarily as severe as breaking or destroying it – created a considerable hurdle to interaction:

- **No, not really. Well, there were, [the worksheet] gave things like now you can do this and do what you want with this. I didn’t explore too much.”**

- **And why is that?”**
  Because I might do something wrong.

No ownership of their interaction is experienced as it is something that they are directed to do for a particular reason. If they had a choice, they would not be interacting with the artefact; there is a fear of access. They are completely detached from the interaction and not even specific directives from an authority figure are always enough for pupils to overcome their fear of the artefact. For example:

- **Okay, were you told you had to do it?”**
  Yes, but I worked with somebody else so, they did all the stuff, I just sat there and watched.

**Category B: Interaction with a technological artefact is through instruction**
In this category, the reluctance to interact associated with Category A no longer prevents pupils interacting with technological artefacts. The interaction is now no longer driven by a directive but is self-motivated. The primary focus of this category is having instruction via some means enable the interaction with an artefact.

This category carries recognition of an instruction-mediated access to interact with an artefact. In the following extract, mediation is by instruction as provided by a manual of some kind. The use of the technological artefact is possible only after, in this case, the instruction book has been read. As in Category A, the ‘interaction hurdle’ is still present. Not using the item correctly could result in the possibility of ‘messing it up’, but the instructions facilitate a mediated entry to the technological artefact:

Read the instruction booklet. Because, ‘ja’, I don’t really like figuring things out myself. I’m sure I could actually mess it up and do something wrong.

Instruction of some kind is required to direct the activity of pupils. The instruction received need not be only in written format, but could be from a variety of sources including oral instruction from an adult. For example, the following extract illustrates how a father has previously given instruction on how to use various artefacts. These artefacts will continue to be used within the context of this instruction. The key here is that the artefacts are used within these parameters to facilitate entry:

Is there anything else you can think of that’s like the cell phone that you don’t need to work with?
A CD player.
Okay so you also happy to fiddle with that?
I’ll fiddle on that.
Why is that?
Ummm, because I don’t know, its just easy to use for me and there is no funny buttons. You press and then, maybe the hi-tech stuff that my Dad has, one of those big speakers and stuff like that, now I won’t fiddle on his stuff. But I know how to use the amp and he showed me how, so, want to make the bass [inaudible] I’ll fiddle on there; I know how to use it. That I will do but I won’t fiddle with anything else.

Unlike Category A, this category carries a recognition that it is possible to have the technological artefact perform a required function. In addition, the interaction is no longer formalised but takes place in a restricted context of specific actions and there is no reference to using prior experience. Furthermore, an artefact would only be used in terms of a directive. That is, interaction will be personally initiated but this will be in the context of following instructions. Interaction will only be as much as is necessary to perform a specific function.

**Category C: Interaction with a technological artefact is through tinkering**

This category is characterised by a self-initiating interaction with a technological artefact by beginning to tinker with it. Unlike the previous categories, there is no need for instruction to enable this interaction. There is no sense of being intimidated by anything to do with the artefact.
The extract below illustrates the idea that self-initiated tinkering takes place. Pupils recognise that an artefact has a variety of functions and set out to determine what they are and make the artefact operate. This tinkering starts in a constrained way and gradually expands to encompass the entire artefact. Although full rights to access the artefact are recognised, there is not an accompanying sense of ownership of the interaction. The description below also shows how Category C is qualitatively different from the previous categories with respect to the concern shown of getting something wrong while interacting with a technological artefact. There has been a shift to where getting something wrong is simply a consequence of tinkering. There is no judgement on the ability to get it right or wrong. Tinkering is personally motivated:

If you had to get a new cell phone, how would you know how to use that, [be]cause it comes with a nice thick set of instructions, do you read the instructions?
No, no, I like finding things, finding out things on my own so I wouldn’t read it.
You aren’t worried about something going wrong?
Well I would be, I’ve already broken two cell phones, blocked them, but ja, no I’m not actually worried about anything.

Interaction in this case takes place in the context of self-initiated free enquiry with prior experience being drawn from to inform the interaction with the technological artefact. Prior experience is used to self-initiate undirected interaction with an artefact. It is recognised that an artefact has a variety of functions and pupils set out to determine what they are and make the artefact operate. Pupils are aware of the potential of the artefact and experience full rights to access the artefact; however, there is not yet a sense of ownership of the interaction. The interaction is a physical, tactile action focussed around the artefact.

Category D: Interaction with a technological artefact is through engaging

This category differs from the previous three in that the method of interaction is now something that is reflected upon and takes place through an engagement with the artefact. The kind of barriers to entry into the space of the technological artefact as typified by Categories A and B continue to be absent and the pupils are creating their own contexts and frameworks within which to work.

In this category, there is no indication that technological artefacts are something to be wary of. The objective of interacting with an artefact is to understand its use and thus a cognitive aspect has been added to the physical action associated with the previous category. This type of interaction provides for real engagement with the technological artefact. As in Category C, interaction takes place in the context of self-initiated free enquiry. However, prior experience is drawn from and supplemented as required to inform the interaction. A variety of methods of doing this are available. In the extract below, it is a backwards and forwards process of engaging that is taking place. The manual referred to in the extract is not necessarily saying how to do something, but rather that a feature is available. Typical of this category is that if there is no additional information available then pupils will simply find out for themselves through a process of investigation:
So if you had to get a video recorder for example with a manual, how would you work out how to use a video recorder?

You would read the manual.

You read the manual, is that the first step?

You would read the manual and you would look at the thing at the same time so as you read the manual they tell you something and you’ll see okay it is there and try it out or if you didn’t have the manual, you just as we say, ‘pieter’ [potter], until you find out.

In the extract below, it is shown that this interaction is not just about tinkering but rather engaging. Information is obtained about the artefact from a selection of sources and it is assessed as a whole to help determine what and how to do what needs to be done. Having this information as a framework is their choice. They are in control and this interaction is a personal experience. The purpose here is to understand both the function of, and how to use, an artefact. It is a conscious process of investigation into all aspects of the technological artefact:

When you get a new radio control car, do you take it apart straight away?

Not really, I first like see how it works, what, why did I buy it first of all, cause it can move and do stuff so then I will find out, think, how would they, for instance how would they make a steering column or how would they make the back wheels with front wheels move, how is that my couple of batteries in the back of the remote or in the car would give it enough or sufficient energy to go to do whatever it is supposed to and how long can it last.

Okay and how do you go about interacting with the car, how do you go about working with the car?

Working with the car, as in opening it?

Ja, if you want to know more about it, if you wanted to work with it, if you want to use it...

First of all I would see what I could do without me opening it first, and then when I open it I will take it apart slowly so that I would remember how to put it back together and then of course I then I will look where does the energy come from, where does the power come from and then how is it regulated in the car and how does it get spread or distributed to wherever it must go.

4. Discussion

An important result of this investigation is the confirmation that there are a number of different ways that students can experience interacting with technological artefacts. Although anecdotally evident, the full extent of how inaccessible many of the technological artefacts in the ‘introduction to engineering’ course may have appeared to some of the students had not been appreciated. The less complex ways of interacting (through direction or instruction) would require the facilitator of a project to ensure that a well-defined and supportive environment be provided to guide these students into what we can now empirically show is, for them, often a potentially intimidating experience. The goal, in this case, should be to develop the confidence of these students in their interaction and take them to the point where they feel confident to initiate interaction with the artefacts in the projects.
‘Introduction to engineering’ courses are often developed with the assumption that a number of students may not have had any real experience of engaging (or even tinkering) with technological artefacts when they enter an engineering degree programme. In our case, the curriculum was designed with the idea that if the opportunity was made available for students to interact with technological artefacts, they would be able to develop a similar level of ability as those students who may have had this experience during their formative years. What had not explicitly been considered was the impact of having students in the class who appear to interact with technology through direction. The reality facing educators, particularly in a context such as South Africa, is that the current students who enrol in engineering degree programmes bear scant resemblance to those who may have entered engineering degree programmes in previous generations. Children who grew up before an era of computers and television often came with ‘hands-on’ hobbies such as building Meccano models, crystal radios, model aeroplanes and boats, or keeping an old car in running order. They would have experienced building tree-houses, dismantling and reassembling toys (and often other items in their homes) and through this kind of activity may have been stimulated to follow a technical career. Our experience is that students entering higher education today have had little exposure to these classical ‘technological’ stimuli and very few have indulged in any form of technical hobby outside of computing.

In a recent study (Reed and Case 2003), we looked at the factors influencing students’ decision to enter a mechanical engineering degree programme. These results indicate that there are a number of students in a class who may not be inherently predisposed to a technological career. Some of the factors emerging from the study include the availability of bursaries, how much they may potentially earn as a professional engineer, and most concerning, mechanical engineering being the least objectionable option from a range of possible choices of study. It is possible that it is these students who would most likely tend to interact through direction or instruction. Furthermore, this could help explain why it is that so many students in the course appear to struggle to embrace the use of technological artefacts in the completion of their projects.

With an increasing number of students entering engineering programmes who would appear to interact with technological artefacts in less advanced ways as described by the results of this study, it is appropriate to consider what action can be taken to address this situation. Putting extra effort into helping students move from these less advanced ways of interacting to more advanced ways would be appropriate if one were to take the view that some of these students could have the potential to become competent engineers if they were simply given the opportunity to develop within a well designed educational environment. It is important to note that although these phenomenographic categories are hierarchical in nature, they do not necessarily form a developmental sequence. As such, it may be possible in some instances for students to quite quickly – under the correct conditions – progress to being able to engage with technological artefacts. With this in mind, an appropriate course of action would be to introduce carefully constructed learning environments where the appropriate ‘scaffolding’ (Bruner 1978) was ensured to enable students to develop to where they could interact with technological artefacts through engagement. However, an important consequence of retaining
students who are, as we have shown, to a large extent intimidated by technological artefacts, is the potential for these students to experience a sense of alienation from the activities that they are expected to be participating in as a class. It would be important to ensure that the scaffolding introduced explicitly addressed this possibility.

References


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