Reading Technological Artifacts: Does technology education help?

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Abstract
Reading technological artifacts is recognised internationally as an important aspect in developing technological literacy. To be read – or critically interpreted, these artifacts are required to be understood as much more than an 'entity as such'. Instead, they must be seen as the embodiment of design and purpose and located in the complex socio-cultural milieu of their inception, development and use.

Philosophical attempts to guide critical interpretations have been supported by focusing on the interrelated dual (physical and functional) nature of technological artifacts (Kroes & Meijers, 2000; de Vries, 2005; Vaesen, 2008). This aspect of the philosophy of technology is the basis of the New Zealand curriculum achievement objectives related to the Nature of Technology strand component known as 'Characteristics of Technological Outcomes' (Ministry of Education, 2007). In this component significant emphasis is placed on students developing understanding of the interrelated physical and functional nature of technological outcomes (or artifacts) and how these outcomes are understood as embedded in their social and historical context.

Exploration into students' ability to read technological artifacts has been a part of a number of research projects undertaken in New Zealand over the last eight years. This focus has been continued in our latest research– the *Technological Literacy: Implications for teaching and learning* (*TL: Imps*) project. In this paper, we share our early findings related to reading technological artifacts and discuss these in terms of previous national and international research findings.

Introduction
Technology as a form of human endeavor involves both the development and production of outcomes which exist in the 'made' world and as such intervene in ways both intended and unintended in the made, natural and social world we both create and/or inhabit. Technology education programmes designed to support the development of technological literacy will therefore require students to be provided with opportunities to understand both the processes of development and the nature of the resulting outcomes. In this paper we are focusing specifically on aspects of learning related to the later of these – the nature of technological outcomes or as they are more commonly known - technological artifacts. Technological artifacts are understood to be products and

systems that result from technological practice to address a need or opportunity. Reading technological artifacts is recognised internationally as an important aspect in developing a philosophical understanding of technology as part of an overall technological literacy (de Vries, 2005; Vaesen, 2008; Frederik, Sonneveld, & de Vries, 2011).

When this technological literacy is framed as 'broad, deep and critical' (Compton, Compton & Patterson, 2011; Compton & France, 2007a), further caveats are placed upon technology education programmes. That is, when students are expected to read or critically interpret such artifacts they are required to understand these artifacts as much more than 'entities as such'. Instead, they must be seen as the embodiment of design, purpose and knowledge and located in the complex socio-cultural milieu of their inception, development, use and disposal. Philosophical attempts to guide critical interpretations have been supported by focusing on the interrelated dual (physical and functional) nature of technological artifacts (Kroes & Meijers, 2000; de Vries, 2005; Frederik, Sonneveld, & de Vries, 2011). This focus is clearly captured in the philosophical strand (known as the Nature of Technology) within the New Zealand curriculum (Compton and Compton, 2011). This strand is comprised of two components. The first being the Characteristics of Technology (CoT) which is focused on the development processes and their surrounds. The second is the Characteristics of Technological Outcomes (CoTO) which is focused on technological artifacts (Ministry of Education, 2007). In the second component significant emphasis is placed on students developing understanding of the interrelated physical and functional nature of technological outcomes (or artifacts) and how these outcomes are understood as embedded in their social and historical context. Developing understanding of knowledge underpinning the development and use of technological artifacts is also important to the ability to read artifacts – particularly that associated with understanding the materials used. This focus is captured in the Technological Products (TP) component of the technological knowledge strand (Ministry of Education, 2007).

Exploration into the ability of students to read technological artifacts has been a part of a number of research projects undertaken in New Zealand over the last eight years. This focus has been continued in our latest research project – *Technological Literacy: Implications for teaching and learning* (*TL: Imps*). In this paper, we present initial findings from a series of interviews undertaken to gather data on how students read technological artifacts. We discuss the initial findings from this project with those from earlier research, both in New Zealand (Compton & France, 2007b) and elsewhere (Frederik, Sonneveld, & de Vries, 2011).

Research Overview

As explained elsewhere (Compton, Compton & Patterson, 2011) the *TL: Imps* project is a national research project funded by the New Zealand Ministry of Education. The project began in July 2010 and is scheduled to run through to June 2013. The aim of the *TL: Imps* research is to explore student technological literacy and document how it can be supported through programmes based on the integration of the three strands of the technology learning area in the NZC (Ministry of Education, 2007). Of particular interest in this research is the way the components work together at different levels of student learning to ensure students progress in each component individually and in such a way as to best support an increasingly sophisticated and holistic technological literacy.

This project provides an opportunity to evaluate the success or otherwise of the latest phase of technology curriculum development in New Zealand in terms of supporting a transformation of students into increasingly technologically literate beings. As part of this project, students ranging from age 5 years to 13 will be interviewed about technological artifacts, both known and unknown. This data will be used to identify the ability of students to read technological artifacts as indicated by their ability to *judge* a known artifact's fitness for purpose, and their ability to *determine* what an unknown artifact might be.

A series of three interviews will be conducted over a two year time period. Round 1 interviews focused on collecting baseline data and were undertaken between March and April 2011. Round 2 interviews focused on collecting data after the completion of the first year of a known technology programme. These interviews were undertaken between October and December 2011 (see Appendix A for interview details). A third round of interviews will be undertaken after the completion of the second year of the technology programme. These are scheduled to occur between October and December 2012. When ever possible, the same students will be interviewed in each round. The participant makeup and interview structure of the interviews to date is provided below.

Interview Participants and Codings:

The 19 schools involved in the research are geographically located throughout New Zealand and include nine primary (year 1- 8), seven secondary (year 9-13) and three composite schools (year 1-13). The schools are a mix of urban and rural and include students from a range of socio-economic and ethnic backgrounds. Ninety two teachers and 1428 students have been involved the project to date. Almost one third of these students (432 or 30%) have been interviewed in Round 1 and/or Round 2. More female (258 or 59.3%) than male students (174 or 40.3%) have been interviewed as reflective of the overall cohort of students involved (748 or 55.8% female and 593 or 44.2% male).

During Round 1 a total of 392 students were interviewed. The majority (290) of these students were interviewed again as part of Round 2. Some of the original students will not be interviewed again until Round 3 as the school they attend was severely damaged in the Christchurch earthquake. Other students have either left their respective school, or were not available on the day of the interview. An additional 43 students were interviewed in Round 2 to replace students who had left. Therefore the number of students in the Round 2 cohort overall was be 333.

The distribution of students interviewed in Round 1 and/or Round 2 by year group is shown in Table 1.

Table 1: Participants by Year Group

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
#	33	31	32	34	33	25	36	32	69	49	26	21	11
%	7.6	7.2	7.4	7.9	7.6	5.8	8.3	7.4	16	11.3	6	4.9	2.5

The artifacts used and questions asked are provided in Appendix A. The student answers to the questions were used to code students as reflective of their ability to judge fitness for purpose of a known artifact and their ability to determine what an unknown artifact was. Students were coded using a 0-4 scale for ability to judge fitness for purpose whereby:

- 0 = Unable to make a judgement. Never heard the term fit for purpose and/or has no idea what it means
- 1 = Makes a judgement on incorrect understanding of term. May or may not have heard term before but considers it refers to a product being 'healthy'
- 2 = Makes a simplistic judgement. Heard term before/never heard term but worked it out – holds a simplistic understanding whereby fitness for purpose means it is able to 'do its job' where the job is its 'technical' function
- 3 = Makes a reasoned judgement. Uses given example to explain how the judgment is based on the artifact in relation to specifications. Links specifications to technical and social considerations such as user-friendliness, user or environmental impact
- 4 = Makes a well-reasoned judgement with a sophisticated explanation. Often linked to more than given example, showing a bigger picture view that includes reference to such things as ease of use/not malfunctioning/environmental impact and/or marketing factors alongside working as intended and often discusses need for evidence before a judgment can be made (e.g. I can't say till I've tested it/evidence from others - prototyping).

Students were coded using a 0-6 scale for ability to correctly determine what an unknown artifact is whereby:

0 = No idea
1 = Suggests an idea – (wrong) unsupported by observation or reasoning
2 = Suggests an idea – (wrong) supported by observation and/or reasoning
3 = Suggests an idea – (wrong) challenged by observation and reasoning – changes idea in keeping with this but still wrong
4 = Suggests an idea – (wrong) challenged by observation and reasoning – changes idea in keeping with this and works out what it is
5 = Suggests right idea - well reasoned
6 = States right – seen before.

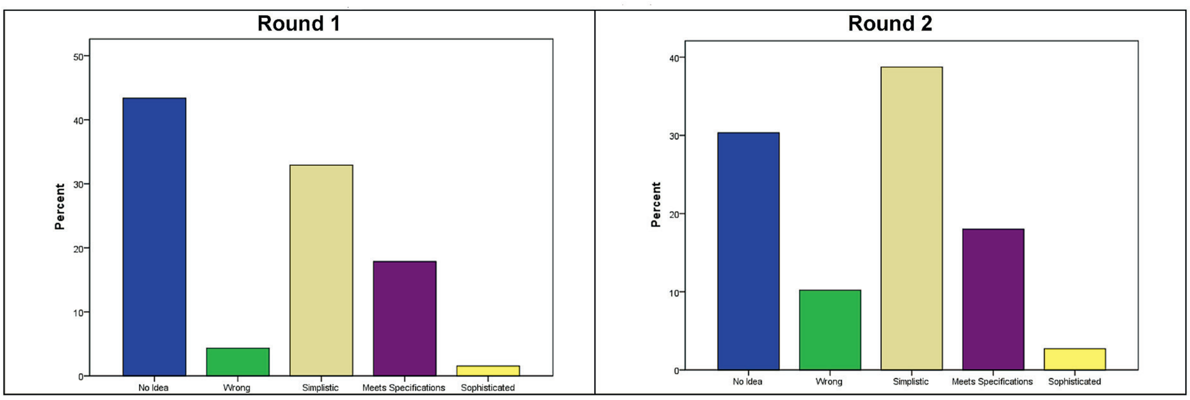
Responses to the questions were also used to make a judgement about achievement level related to CoT, CoTO, and TP. The indicators of progression were used as a guide for this coding (Compton and Compton, 2011a; 2011b) where 0 = pre-level 1, 1=1 through to 8=8 for all components.

Findings

Reading an Artifact: Judging Fitness for Purpose

A total of 392 students were coded in terms of their ability to judge the fitness for purpose of the known artifact in Round 1 and 333 in Round 2. Figure 1 presents the results of this coding.

Figure 1: Fitness for Purpose of Known Artifact



Of the 392 students in Round 1, 170 (43.4%) had no idea what fit for purpose meant and therefore could not make a judgment on the juice carton. A further 17 (4.3%) held a wrong understanding and therefore their judgment of the juice carton was flawed. For example, if a product was fit for purpose it made you 'fit' or 'healthy'. One hundred and twenty nine students (32.9%) had heard the term before, or worked out the meaning from the words, and could use this to make a simplistic judgment on the juice carton as being able to 'do its job' or not. The majority of these students considered the product was fit for purpose as its 'job' was to provide someone with a drink of juice. Seventy students (17.9%) understood fitness for purpose in terms of the product meeting its specifications and could explain their judgment of the juice carton in terms of such things as convenience, size and ease of use. Six students (1.5%) provided a more sophisticated explanation of fitness for purpose and included the proviso that to make a judgment of the juice carton's fitness for purpose required evidence from its performance in situ.

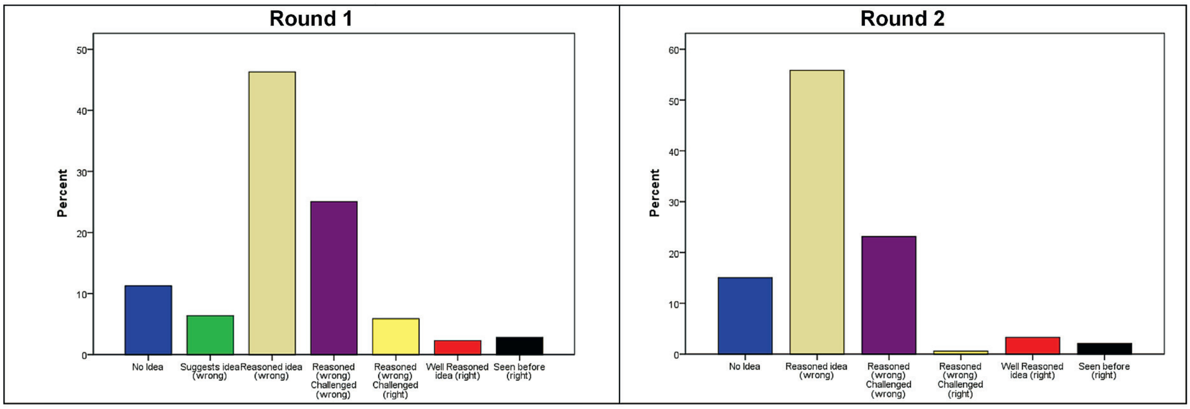
Of the 333 students in Round 2, 101 (30.3%) had no idea what fit for purpose meant and therefore could not make a judgment on the Bobble. A further 34 (10.2%) had a wrong understanding and therefore their judgment of the Bobble was flawed. One hundred and twenty nine students

(38.7%) had heard the term before, or worked out the meaning from the words, and could use this to make a simplistic judgment on the Bobble as being able to 'do its job' or not. The majority of these students considered the product was fit for purpose as its 'job' was to provide someone with a drink of water. Sixty students (18%) understood fitness for purpose in terms of the product meeting its specifications and could explain their judgment of the Bobble in terms of such things as convenience, shape, quality of water, environmentally friendly (reusable or recyclable). Nine students (2.7%) provided a more sophisticated explanation of fitness for purpose and included the proviso that to make a judgment of the Bobble's fitness for purpose required evidence, often scientifically based analysis of the water quality, from its performance in situ.

When this data was explored in terms of year groups there was an overall trending down of the 'no idea' and 'wrong' categories as the year group increased and a trending up of the remaining categories in both Round 1 and 2.

Reading an Artifact: Determining an Unknown Artifact

A total of 391 students were coded in terms of their ability to determine an unknown artifact in Round 1 and 333 in Round 2. Figure 2 presents the results of this coding.



Of the 391 students in Round 1, 44 (11.3%) had no idea what the item might be and did not make any suggestions at all. Twenty five (6.4%) students suggested (wrongly) what the item might be but provided no support for this idea. One hundred and eighty one students (46.3%) provided a reasoned suggestion (which was wrong) for what the item might be. The majority of these students focused on the physical nature of the item – making links to things they had seen before and did not self-challenge these ideas through observation and/or further explorations. For example, many stated it was a toy because it had wheels. Ninety eight students (25.1%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through a focus on the linked physical and functional nature of the item – using observation of materials, shape and exploration of function. All suggestions remained incorrect however. The majority of these students identified the 'chefn' branding and concluded the item must be a cooking utensil of some sort. Twenty three students (5.9%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through observation of materials, shape and exploration of function and coming up with the right answer. An additional 9 students (2.3%) came up with the right answer after undertaking a sophisticated reasoning exercise based on a combination of material properties, shape and exploration of function. Eleven students (2.8%) had seen the item before and therefore stated the right answer without any reasoning.

Of the 333 students in Round 2, 50 (15%) had no idea what the item might be and did not make any suggestions at all. No students made a suggestion as to what the item might be without providing support for their idea. One hundred and eighty six students (55.9%) provided a reasoned suggestion (which was wrong) for what the item might be. The majority of these students made links to the physical nature of the item – making links to things they had seen before and did not self-challenge these ideas through observation and/or further explorations. For example, many stated it was a muzzle for a dog because of its shape and the 'dog collar' part. Seventy seven students (23.1%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through a focus on the linked physical and functional nature of the item – making observations of materials, different fastenings, shape and exploration of how things worked together. All suggestions remained incorrect however. The majority of these students identified the item must be for use on a limb of some sort because of its adjustable fastenings. Only 2 students (0.6%) made two or more suggestions of what the item might be, challenging their initial ideas and supporting new ideas through observation of materials, shape and exploration of function to come up with the right answer. An additional 11 students (3.3%) came up with the right answer after undertaking a sophisticated reasoning exercise based on a combination of material properties, shape and exploration of function. Seven students (2.1%) had seen the item before and therefore stated the right answer without any reasoning.

When this data was explored in terms of year groups there was no obvious overall trending in either Round 1 or 2. When the data was re-cut across three categories based on the nature of the reasoning rather than the right answer, the level of reasoning showed some overall trending up as year group increased in Round 1, but this trend was not apparent in Round 2.

Analysis of results

In Round 1 almost half of the students (47.7%) could not make a judgment of the product's fitness for purpose. In Round 2 this figure had reduced to 40.5%. There was a corresponding increase (from 32.9% in Round 1 to 38.7% in Round 2) in the percentage of students who could make a simplistic judgment, and very slight increases in judgments based on specifications (from 17.9% to 18%) and more sophisticated judgment (1.5% to 2.7%).

In both Round 1 and 2, the majority of students could make a reasoned suggestion as to what an unknown artifact might be. Only 17.7% were unable or unwilling to do so in Round 1, and this figure reduced slightly to 15 % in Round 2. There was an increase (from 46.3% in Round 1 to 55.9% in Round 2) in the percentage of students who suggested a reasoned but wrong idea, and very slight reduction in challenging but incorrect ideas (from 25.1% to 23.1%) and a larger reduction in challenging resulting in a change to the correct idea (5.9% to 0.6%). There was a slight increase (from 2.3% to 3.3%) in the percentage of students correctly determining the artifact based on more sophisticated reasoning. Little change was seen in the percentage of students who had seen the item before (2.8% to 2.1%).

Based on these interim findings it would appear the technology programmes have not resulted in any significant impact on student ability to read technological artifacts. At best there may be some evidence of a slight shifting of students from being unable to judge a product as fit for purpose at all, to being able to make a simplistic judgment. There was no clear increase in student ability to determine an unknown artifact.

In contrast to this, student understanding related to Characteristics of Technology (CoT), Characteristics of Technological Outcomes (CoTO) and Technological Products (TP) showed a clear progression from Round 1 to Round 2. The greatest shifts overall were those related to CoT and TP. CoTO also showed good progress from pre-level 1 to level 1. The shifts between Round 1 and 2 are summarised in Table 2:

Table 2: Summary of Shifts between Round 1 and 2

	CoT	CoTO	TP
Pre-level 1	55.6% to 20.8% Decrease of 34.8%	52.6% to 21.4% Decrease of 31.2%	41.1% to 5.1% Decrease of 36%
Level 1	30.9% to 47% Increase of 16.1%	30.9% to 51.5% Increase of 20.6%	43.1% to 63% Increase of 19.9%
Level 2 or above	13.5% to 32.2% Increase of 18.7%	16.6% to 27.1% Increase of 10.5%	15.8% to 31.9% Increase of 16.1%

Discussion

At this early stage of the research it seems clear that the technology programmes of learning these students are currently participating in are providing opportunity for many students to increase their understanding of the components CoT, CoTO and TP. There was a greater percentage increase a level 2 and beyond related to CoT and TP than CoTO. In addition there is some evidence to suggest a small increase in student ability to read a known artifact (that is, judge its fitness for purpose), but no increase in reading an unknown artifact (that is, determine what it is).

As indicated earlier, for students to be able to read an artifact they must be able to make sense of that artifact as part of a wider sociocultural context drawing from the nature of technological artifacts and the knowledge of their material makeup. Being able to make a judgment of an artifact's fitness for purpose has a strong relationship to understanding CoT and TP - particularly at level 2 and above. Research undertaken in New Zealand during 2004-2006 found the majority of students found it very difficult to make normative judgments about technological outcomes and instead consistently used a personal like/dislike stance rather than using an understanding of materials used or the concept of fit for purpose as judgment factors (Compton & France, 2007b). This would indicate pre-level 1 understanding of CoT. Our initial findings would therefore appear to indicate that the movement in terms of student CoT and TP understanding may be related to the small improvement in reading a known artifact.

The findings associated with reading *unknown* artifacts are at this stage not particularly indicative of anything! While many students did seem to be developing a greater understanding of the physical and functional nature of artifacts, as indicated in the increased percentage of students working at level 1 CoTO, this does not appear to have translated into an ability to use such knowledge to 'decipher' the clues inherent in the artifact. These findings resonate with those reported in a small research pilot study in the Netherlands where it was found that "Both experienced and inexperienced teachers do not fully grasp the concepts related to the dual nature of technical artifacts" (Frederik, Sonneveld, & de Vries, 2011, pg 286). In addition, in both the Netherlands and earlier New Zealand research it was found that when teachers or students were attempting to work out what a 'mystery' object was, they tended to focus more on the physical nature without relating it to the functional nature. Understanding the relationship between the physical and functional nature is a key aspect of level 2 CoTO. The smaller percentage shift above level 1 in CoTO related understanding may help explain the lack of progress in determining what an unknown artifact is. Alternatively it may be that determining an unknown artifact requires a higher level of understanding than making a judgment as to a known artifacts fitness for purpose. These relationships require explored further exploration and will be a focused on again during school by school and the Round 3 analysis.

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Appendix A: Interview Props and Questions

Known Artifact		
Round 1	**Round 2**	
		Why has this product been developed? What materials have been used to make the packaging (Round 1)/the bottle (Round 2) Why do you think these materials were selected? How do you think this is made? How does the juice get inside the packaging? (Round 1) How do you think the filter works? (Round 2) Do you think this is a good form of packaging for a juice product? Why/why not? (Round 1) Do out think this is a good product? Why/why not? (Round 2) Have you heard the term fit for purpose before? *If student has come up with a useable definition of fit for purpose…* Do you think this a product is 'fit for purpose'? Why/why not

Unknown Artifact		
Round 1	**Round 2**	
		What do you think this is? Why do you think this? (prompt around materials, shape, parts etc) How do you think it might work? *If student has come up with a firmish idea of what it is and its use…* Who do you think it was designed for? Why do you think it was designed? Do you think it is a good design? Additional Questions for Round 2 What does something have to have for you to call it a 'good design'? *If student knows what fit for purpose means…* What do you think the relationship between fit for purpose and 'good design' might be?