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## **Validating an instrument for use in assessing the technological literacy of upper secondary school students**

**Melanie B Luckay & Brandon I Collier-Reed**

*Centre for Research in Engineering Education & Department of Mechanical Engineering,  
University of Cape Town, South Africa*

mb.luckay@uct.ac.za, brandon.collier-reed@uct.ac.za

In this paper an instrument for assessing upper secondary school students' levels of technological literacy is presented. The items making up the instrument emerged from a previous study that used a phenomenographic research approach to explore students' conceptions of technological literacy in terms of their understanding of the *nature of technology* and their *interaction with technological artefacts*. The instrument was validated through administration to 969 students on completion of their 12 years of formal schooling. A factor analysis and Cronbach alpha reliability co-efficient was conducted on the data and the results show that a four-dimension factor structure (namely, *Artefact*, *Process*, *Direction/Instruction*, and *Tinkering*) strongly supported the dimensions as developed during the original phenomenographic study. The Cronbach alpha reliability co-efficient of each dimension was satisfactory. Based on these findings, the instrument has been shown to be valid and reliable and can be used with confidence.

### **Introduction**

Technology education is typically enacted in schools through a subject referred to as Technology (Lewis, 1999). Many claim that the end-product of technology education is technological literacy (for example, Waetjen, 1993). However, there are numerous definitions of technological literacy. Some claim that the definition varies by discipline (Gagel, 1995 & 1997), while others (e.g., Garmire and Pearson, 2006) have argued that the definition can be confounded by socio-cultural context, where the social, cultural, educational and work backgrounds of individuals influence their understanding of technological literacy.

The uncertainty in definition implies that technological literacy is open to many interpretations. It is far from straightforward to assess student's level of technological literacy - the outcome of technology education. An instrument to quantify a student's level of technological literacy might give an indication of how effectively schools develop technological literacy in students and where improvements can be made. However, attempts to assess technological literacy using instruments of this nature have had limited success, primarily because instrument development is affected not only by the fact that technological literacy is a multi-dimensional term, but also that it is questionable whether a single instrument can be used for varying target populations, and importantly, that there is limited literature in the area to support claims.

Consequently, instruments currently available are largely influenced by the views and discipline of the authors. Our review of available instruments suggests that these provide disparate information, where one is unable to obtain a 'full picture' of what it means to be technologically literate. Garmire and Pearson (2006) have argued that one cannot administer a generic instrument as the 'level of technological literacy' changes to a particular group, for instance, to adolescents and adults. Nonetheless, a robust instrument to assess technological literacy is generally lacking. The work reported in this article presents the outcome of the development of such an instrument.

### **Theoretical framework**

In a comprehensive analysis of technological literacy, Dakers (2006) highlights the critical need to engage young people in a new literacy – one in which they can navigate their way

through a technologically-mediated world. He claims that students seldom have a discourse or literacy in this area, and thus have unreflective views and opinions about the advantages and disadvantages of technology. As a consequence many students reduce the concept of technology to raw materials – “stuff that we can transform into artefacts” (p. 2) – a view suggesting that humans control technology for our needs and wants. This way of conceptualising technology is simplistic and has to change to a more sophisticated level of thinking – through technology education (Dakers, 2006). Indeed, the role of technology education should be that of a roadmap to steer students’ thinking to evolve beyond their current basic understanding of technology as artefacts (computers, cars, televisions, toasters, genetically engineered tomatoes and so on); to a more sophisticated view that includes the awareness of knowledge and processes that create the artefacts, as well as the implications thereof (ITEA, 2000).

While Dakers (2006) provides a view of how students experience technological literacy, the expert – or considered – view of what it means to be technological literate is more nuanced and developed in its conception. Even though, as we suggested earlier, there is no single definition of technological literacy, recent work has begun to draw together some of the different views in a move toward unifying three of the major components or dimensions of technological literacy; a model which describes an individual’s level of technological literacy more holistically. The three-components are knowledge, capabilities, and critical thinking and decision-making (NRC, 1996; Garmire & Pearson, 2006). First, the knowledge dimension of technology literacy includes both factual knowledge and conceptual knowledge. Second, the capabilities dimension relates to how well a person can use technology (defined in the broadest sense) – and influences how a person solves problems during the design process. Lastly, the critical thinking dimension has to do with ones approach to technological issues. The three-part model is commensurate with a study of Collier-Reed (2006), who defined technological literacy broadly as ‘understanding the nature of technology, having a hands-on capability and capacity to interact with technological artefacts, and ... be able to think critically about issues relating to technology’ (Collier-Reed, 2006, p. 15), a definition that has been adopted for this current work.

The challenge, though, is to quantify students’ levels of technological literacy. Boser et al. (1998) have argued that there is ‘no widely accepted standardized instrument suitable for assessing the broader construct of technological literacy’ (p.5). They claim that the ‘affective domain’ (cf. attitudinal studies such as PATT [Pupils’ Attitudes Toward Technology] (Raat & de Vries, 1985) is used ‘as an alternative way to assess technological literacy’ (p.5), often without satisfactory results. There have been various PATT (Raat & de Vries, 1985) conferences for which the proceedings provide a useful starting point. The PATT questionnaire is one of the best known technology-related instruments. In its early form, the questionnaire included a free-response, or essay, section that was meant to be assessed with reference to the ‘concept’ scales which were derived from literature as well as through interviews with professionals in the field – ie., primarily reflecting the expert view of the dimensions. In the preliminary data analysis of the PATT-USA study, ‘none of the categories of responses to the essay question correlated with anything’ (Bame & Dugger Jr, 1989, p.315) in the ‘concept of technology’ scales. Once the ‘concept’ scales as such were shown by the PATT-USA study not to be useful, the expectation could have been that the essay section would be analysed differently for future uses of the PATT questionnaire. In fact, in a use of the PATT questionnaire in Hong Kong (Volk, Yip, & Lo, 2003), where a modified form of the PATT-USA questionnaire was used, the ‘concept’ questions were not included at all.

We suggest that the researchers recognised that what the students understood the concept of technology to be was not necessarily commensurate with how the experts agreed to define the

concept. In the modified questionnaire, the essay question remained, but interestingly, there appeared to be no mention of ‘concepts’ developing from it in the presentation of the results. With the ‘concept’ section omitted, there appeared to be no further attempt to analyse the qualitative data, only the quantitative data relating to pupils’ attitudes towards technology, was analysed. Our argument is that a large part of the reason why students could not distinguish the concept scales was that they were based on a review of technology literature and consultation with experts in the field of technology and technology education. As such, they did not necessarily represent the ways that students conceive of technology. A more useful approach could have been, in the first instance, to determine the ways in which students did conceive of technology and then develop the questions for the ‘concept’ section of the PATT questionnaire from that perspective.

Similarly, but focussed more specifically on technological literacy, a significant study that has investigated students’ levels of technological literacy was undertaken in 2001 by Saskatchewan Education in Canada. In this study, they looked to assess levels of technological literacy and provide ‘a snapshot of their [students’] skills, knowledge, attitudes and practices’ (Saskatchewan Education, 2001, p.1). For this investigation, they define technologically literate students as students that have the ability to ‘understand how technology and society influence one another and ... [are able to] use this knowledge in their everyday decision making’ (p.1). One feature of the Saskatchewan Education data collection process is the assessment criteria against which levels of capacity and capability of the pupils were measured. These consisted of a set of levels developed by the ‘stakeholder representatives’ (Saskatchewan Education, 2001, p.62) that included various civil society and governmental organisations with educational as well as technical expertise. These are, as such, an ‘expert’ scale against which to judge levels of capability and capacity. However, there is no guarantee that students of this age will conceive of technology or interact with technological artefacts in terms of the levels developed by the stakeholders – a situation borne out by the nature of some of the results that emerged.

It is evident from these two studies that making use of expert views of what it means to be technologically literate in the development of dimensions for use in an instrument has the potential to be problematic. The results are influenced by students simply not understanding, or indeed recognising, some of the more advanced conceptions – dimensions – of technological literacy. What may have been more relevant, or useful, would have been to determine, from the students’ perspective, the range of ways that it was possible to conceive technological literacy and to base the dimensions used on this scale. This could then have been compared and contrasted with the scale determined by experts. We argue that this would give a better indication as to the actual technological literacy levels of students and not simply the levels based on what ‘experts’ expect.

Students’ conceptions of a phenomenon, in this case, technological literacy, can be described using phenomenography. Phenomenography is an empirical research tradition that was developed to answer questions about thinking and learning, especially in the educational context (Marton, 1986). Ways of conceiving a phenomenon have been shown in many studies of many different phenomena, to be limited in number with respect to a particular phenomenon (Trigwell, 2000). In other words, for any phenomenon, there are a limited number of qualitatively different ways that this phenomenon could be conceived and phenomenography describes the variation in conceptions of this phenomenon across a group of individuals; a collective (Dall’Alba et al., 1993; Trigwell, 2000). Phenomenographic research has as its outcome a set of categories of description that characterise the variation in the way a phenomenon may be conceived. This ‘complex’ of categories of description form what is referred to as an outcome space. The categories contain distinct groupings of descriptions of conceptions of a phenomenon. Central to an outcome space is that the

categories will be logically related. Once the outcome of a phenomenographic analysis has been finalised in terms of categories of description, an instrument could be developed where the dimensions – which would develop out of the categories of description – would then be reflective of students' conception of that phenomenon. For example, Trigwell and Posser (2004) successfully developed an instrument, the *Approaches to Teaching Inventory* (ATI) using phenomenography to develop the dimensions utilised in the instrument.

Using the phenomenographic research approach, Collier-Reed (2006) conducted a study that explored students' conceptions of technological literacy. These studies were conducted with the purpose of understanding how senior high school students in grades 11 and 12 conceive of and interact with technology; which he argued captured the key dimensions of what it was to be technologically literate. Drawing on the methodological approach described by Trigwell and Posser (2004), the outcome of this study (see for example Collier-Reed, 2006; Collier-Reed, Case & Linder, 2009 and Ingerman & Collier-Reed, 2011) informed the development of an instrument that could be used to assess a student's level of technological literacy.

### **Developing the instrument**

This study focusses on the refinement and validation of a widely-applicable and distinctive instrument for assessing students' levels of technological literacy. The development and validation of the instrument has drawn extensively on prior work undertaken by the authors (Luckay & Collier-Reed, 2011 a & b). In earlier work, as described above, dimensions of technological literacy were developed (Collier-Reed, 2006) which, it was argued, collectively satisfied the core content requirements for what it means to be technologically literate. Using a phenomenographic analysis of interview data, five qualitatively different ways of conceiving the *nature of technology*, and four qualitatively different ways of conceiving *interacting with technological artefacts* (Collier-Reed, et al., 2009) were described. In order to classify students' responses relative to these categories of description, a series of statements describing the dimensions of technological literacy were developed. In order to ensure congruence between the students' responses and the categories, sections of an interview by such students relating to a specific category were 'assigned' to a dimension. These interviews were then reanalysed, finally resulting in a number of clearly defined statements (nominally in the students' own words) pertaining to each category.

As an example of how a section from an interview was used in the development of a statement, consider the following extract that was classified as belonging to the category 'Technology is conceived of as an artefact':

Well, it's a bit complicated, firstly. It's *very technological*. It's exactly what I was talking about, what I said *complicated wires* and *things that you don't understand*, it *looked* like technology. (Collier-Reed, 2006, p.123 – Italics in original)

From this interview extract, the following representative statement was constructed: *Things with complicated wires and parts that you don't understand are technology*. Importantly, this process ensured that the statements derived from this process is the students' own comments, and are thus in the style to which they can relate. Consequently, the pilot instrument was defined by 41 statements constructed in this way. There were 25 statements relating to experiencing the *nature of technology*, and 16 statements relating to the experience of *interacting with technological artefacts*. After refinement of the original instrument, where the focus was also on clarity and readability of items, the revised instrument remained valid and reliable (Luckay & Collier-Reed, 2011a&b) – with data being collected from 1064 students across two pilots.

During the first pilot (Luckay & Collier-Reed, 2011a), the instrument was administered to 435 students early in their first year of study at the University of Cape Town. The groups were split between engineering (198) and commerce (237) students. Exploratory factor

analysis supported the existence of six dimensions, offering notational support for the distinctions between artefact, process, direction, instruction, tinkering and engagement. These findings were used to refine the item pool for clarity. Items that showed factor loadings less than 0.3 were deleted from further analyses. The result was a 23-item survey, which was adjusted to a 30-item survey after some of the items were re-considered by the authors to ensure that the items fit the dimension for conceptual clarity.

Two additional pilots were conducted in order to further clarify the dimensions. In Pilot 2, the 30 item survey was administered to 629 high school and first-year university students. The group was diverse consisting of students at the end of high school and those entering their first year of university, but all in the same age range from 17 to 18 years old. Additionally, the students at university were from diverse faculties, namely, engineering, commerce and arts. Exploratory factor analysis suggested that a five rather than a six dimensional solution was more interpretable in terms of the factors formed (Luckay & Collier-Reed, 2011b). The *Direction* and *Instruction* scales came together during the factor analysis, suggesting that students regarded *Direction* and *Instruction* in similar ways. This suggested that *Direction* and *Instruction* should be combined, and that a new combined scale should be formed. Moreover, the factor analysis suggested a new 27-item survey be formed, with three items being discarded as their loadings were less than 0.3. However, the researchers elected to retain the three items as it provided better conceptual clarity, and thus a 30-item survey was retained.

The resultant 30-item instrument was used in the present study. Data were collected from 969 students within their first three weeks of study at the University of Cape Town. The sample was drawn from the Engineering and the Built Environment (312), Health Sciences (80), Science (289) and Humanities (288) faculties. Participants were required to supply biographical information including their age, gender, current degree programme, and high school attended. From this information, it was determined that the sample consisted of 480 (50.3%) males and 475 (49.7%) females – 14 of them did not indicate their gender. The average age of the students was 19 years (SD = 2.28) – 24 students did not indicate their age. The instrument was administered by the authors to ensure consistency in the instructions given to the students and to answer possible queries. Participants were required to mark on a seven-point Likert scale (Cohen, Manion, & Morrison, 2000) their level of agreement with each item on a scale ranging from *Strongly Disagree* to *Strongly Agree*. The data collected from the students were used to examine the validity and reliability of the instrument. As a first step, a factor analysis was performed to cluster variables (Field, 2005). The sample size for the present study was appropriate to perform such an analysis as Tabachnick & Fidell (2007) suggest that ‘it is comforting to have at least 300 cases’ (p. 613). Additionally, Nunnally (1978) recommends that the ratio of the items to subjects is ten to one, that is, 10 cases for each item to be factor analysed. Others have suggested 5 cases for each item (Tabachnick and Fidell, 2007). The data collected thus meet the requirements for both sample size and case to item ratio.

## Results

### Validity and reliability

The data were collected from 969 students across four faculties at the University of Cape Town and used to examine the validity and reliability of the instrument by performing a principal component factor analysis followed by a varimax rotation.

**Table 1.** Factor loadings for a modified version of the instrument ( $n=969$ )

Item No.	Artefact	Process	Direction/ Instruction	Tinkering
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27	0.70			
25	0.67			
29	0.62			
03	0.57			
22	0.41			
14	0.35			
28		0.73		
26		0.67		
19		0.63		
23		0.61		
15		0.47		
09		0.46		
10		0.42		
01		0.39		
17			0.78	
12			0.78	
16			0.76	
30			0.66	
11			0.64	
24			0.54	
20			0.53	
07				0.74
05				0.69
08				0.61
02				0.39
% Variance	7.55	11.34	18.30	4.84
Eigenvalue	2.00	2.95	4.76	1.26

During this analysis, careful attention was given to the dimension *Engaging* as it manifested itself in the data. In the original phenomenographic analysis from which this dimension developed, engaging with a technological artefact was described as taking ‘place in the context of self-initiated free enquiry with prior experience being drawn from, and supplemented as required, to inform the interaction’ Collier-Reed (2006, p.101). The original study suggests that this dimension is not strongly experienced by students of this age – and is an advanced conception; a view supported by an analysis of the current data. Removing the questions associated with this factor in a five factor solution resulted in a more robust and reliable four factor solution as presented in Table 1. The impact of this decision will be discussed below.

Overall, the percentage variance accounted for by the different scales ranged from 4.84% to 18.30%, with a total variance accounted for being 42.03%. Table 1 shows that the eigenvalues ranged between 1.26 and 4.76 for the four dimensions.

For the revised instrument, the Cronbach alpha co-efficient was used as an index of scale internal consistency. A careful analysis of the factor loadings as well as the Cronbach alpha co-efficients of the *Tinkering* factor indicated that it would be appropriate to omit Item 06 from the instrument. Table 2 shows that the internal reliability (Cronbach alpha co-efficient) ranged between 0.63 and 0.84. Overall, these results indicate that the internal consistency for the instrument is satisfactory (Field, 2005; Kline, 1999).

**Table 2.** Cronbach alpha coefficient for the modified version of the instrument

Category	Scale	No. of Items	Cronbach alpha coefficient
Nature of	Artefact	6	0.63
Technology	Process	8	0.66
Interacting with a	Direction/	7	0.84
Technological	Instruction		
Artefact	Tinkering	4	0.64

Taken together, the results for the factor analysis, as well as the index of scale reliability (Cronbach alpha reliability index), suggest that the instrument is reliable and valid to use for upper secondary school and first year university students. The final version of the instrument consists of 25 items and is presented in Appendix 1.

### Discussion and concluding remarks

The development and validation of the instrument – to determine students’ levels of technological literacy – is timely given the renewed focus internationally on the importance of developing a technologically literate youth (Ingerman & Collier-Reed, 2011). The instrument was rigorously developed, captures the important dimensions of technological literacy, and provides educators and researchers with an accessible means of determining students’ levels of technological literacy. The factor structure for the instrument shows congruence with the nature of the categories that emerged from the original phenomenographic analysis. All items have a factor loading of at least 0.35 on their *a priori* scale and no other scale. Furthermore, the internal consistency reliability estimate (Cronbach alpha coefficient) for each of the dimensions of the instrument, was comparable with past studies (ibid).

The authors’ previous work (Luckay & Collier-Reed, 2011a&b) has described how the original dimensions that emerged from the phenomenographic study are currently represented in the factors. These factors usefully straddle the product / process divide with respect to the *nature of technology* on the one hand and students who shy away from *interacting with technological artefacts* versus those who are uninhibited in their interaction with these artefacts through tinkering on the other.

For the scale *Direction/Instruction*, in Pilot 1 (Luckay & Collier-Reed, 2011a), the results suggested that the scale *Instruction* was less useful as a stand-alone scale. However, in Pilot 2 (Luckay & Collier-Reed, 2011b), and in the present study, the reliability co-efficient suggest that combining the scales *Direction/Instruction* was more meaningful (the Cronbach alpha reliability was 0.83) (Table 2). Interestingly, the fact that the two scales merged in the factor analysis (Table 1) suggest that the students could not distinguish between the teacher was directing them or instructing them. Students see *Direction* described by Collier-Reed (2006) as:

The result of a directive by someone. It is not something that happens spontaneously as there is reluctance to making the 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. (p. 298)

Collier-Reed described *Instruction* as ‘receiving instruction via some means which enables the interaction with the artefact’ (p. 299). Thus, it could be that students preferred being helped or guided to ways of initiating their interaction with a technological artefact. It is likely that these students lacked the spontaneity to interact with a technological artefact independently. The results from this study could have implications for both professional development programs for teachers and classroom practices in South Africa. This instrument provides an important means of monitoring their teaching – particularly in cases where there is a blurring between directing and instructing students. Here, teachers might adjust their

learning environment towards a more focused promotion of a technologically literate environment.

For the scale *Tinkering*, the scale plays an important role in distinguishing groups. This scale is described by Collier-Reed (2006) as:

characterised by a self-initiating interaction with a technological artefact by beginning to tinker with it...[T]here is no need for instruction to enable the interaction. There is no sense of being intimidated by anything to do with the artefact...[They] recognise that an artefact has a variety of functions and set out to determine what they are and make the artefact operate (ibid, p. 299-300).

The fact that students are able to self-initiate their interaction with a technological artefact implies that these students have moved beyond being directed or instructed to interact with an artefact. They most likely have the skill, ability and understanding to interact with an artefact in a more sophisticated way. Thus, it could imply that whatever level of academic development, some students have an innate ability to interact with a technological artefact, without being initiated by some form of direction or instruction from an outside source. Students who have the ability to self-initiate through tinkering might have better candidates for technical programmes, like Engineering. In fact, comparing the technological literacy of students across faculties, Luckay & Collier-Reed (2011b) found that Engineering and Science Exposition students are more likely to tinker than Arts or Commerce students, however further research is required, as the questionnaire could ultimately be used as a tool to select students for technical programmes like Engineering.

Based on these findings, the instrument has been shown to be valid and reliable and can be used with confidence in future research.

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### **Appendix 1: TPI Items**

Technology is a person making something to solve a problem and improve quality of life.

I would rather play around with a technological thing than waste time first reading instructions about how to do it.

A CD is only technology when you put the CD into a computer and then copy music onto it.

It is fun figuring out how technological things work without being given instructions to follow.

When I see a new technological thing, the first thing I want to do is play around with it to see what it can do.

I like opening up technological things to see what's inside.

Technology is an idea that has been put into place by someone to help people.

Technology is about using scientific knowledge to make something.

I would rather get someone else to work a technological thing. I might get it wrong or mess it up.

Only with instructions, I would be able to find how to do what I want with a technological thing.

Technology is all about computers and other electronic and electrical things like that.

Technology is making use of knowledge people have about something and using this to solve a problem.

Only if someone first shows me how to do something with a technological thing, then I can use it.

When using technological things, instructions tell me exactly what to do – and only then I can do it.

Technology is using knowledge and skill to develop some product.

I would rather watch someone work with a complicated technological thing instead of trying to do it myself.

Things with complicated wires and parts that you don't understand are technology.

Something is technology because a person had a plan that was put into practice by making it.

I always seem to do something wrong when I try to use technological things.

A television is technology only when you watch a movie on it using signals from the air.

Technology is about solving a problem.

An amplifier or CD player becomes technology when it is switched on.

Technology is the planning and research of something and then the making of it.

A washing machine thrown on a rubbish dump with no motor or wires is no longer technology. It is just a thing.