Technological Profile Inventory (TPI): Determining First Year University Students’ Levels of Technological Literacy

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In this article we describe first year university students’ levels of technological literacy. An instrument, the Technological Profile Inventory (TPI), found to be valid and reliable was used to determine these students’ levels of technological literacy. The instrument was based on a rigorous qualitative analysis of interview data which was in turn informed by categories that emerged from a phenomenographic analysis. Data were collected from 198 Engineering and 237 Commerce students and the items subjected to exploratory factor analysis. Profiles of students’ scores on the dimensions Artefact, Process, Direction, Instruction, Engaging and Tinkering were generated. On the whole an average student in the sample could be considered to have a reasonable level of technological literacy based on the dimensions in the TPI. In the category ‘Nature of Technology’ there were a significant number of students who conceive of technology as a product, a less sophisticated conception of technology. The higher levels of agreement in conceiving technology as a Process rather than an Artefact suggests that these students entered their first year university programme with at least a basic level of technological literacy, albeit a level higher than that of an artefact. The results suggest that students typically have a reasonable level of technological literacy when they arrive at university – which suggests that teachers are managing to fulfil the requirements in the NCS in addressing technology education.

Introduction
In 1994, South Africa saw a significant shift toward a non-racial and democratic society. This shift required social changes to ensure that the country could cater for its people irrespective of race. Such a challenge necessitated a curriculum re-structure, which resulted in Curriculum 2005(C2005) (Department of Education, 1997), which, after many revisions, was re-named the revised National Curriculum Statement (NCS) [rNCS] (DoE, 2002), and then the National Curriculum Statement (NCS). Subsequently, the National Curriculum and Assessment Policy Statement (CAPS) (DoE, 2011) was formulated to amend the NCS in order to improve its implementation– with the amendments coming into effect in January 2012.

A country in transformation requires a workforce highly knowledgeable of current technologies to develop viable economy (Pudi, 2007). Technology, in general, is the engine house of the development and prosperity of any nation in terms of its historical, cultural, social and economic perspectives (Poon, 1994). Technology plays a role, not only in society and culture, but in education through technology education. Technology education should start at school level for learners to become technologically literate (Lewis, 1999).Indeed, after 1994, technology education was introduced in C2005 through the learning area (or subject) Technology. Of the eight learning areas in C2005, Technology was a completely new learning area as it was not part of the pre-1994 curriculum. This lack of established history as a learning area (McCormick, 1997) implies that there is limited knowledge of what technology education in the Technology learning area entails, that is, in terms of its aims, rationale, content and curricula (Daugherty &Wicklein, 2000; Ankiewicz, 1995). Indeed, this lack of clarity is evident, for instance, in the positioning of the Technology learning area in the curriculum. Technology as an area of study in the curriculum was at risk of being discarded, but emerged as a stand-alone learning area because it was seen as an essential element of the school curriculum (Daugherty &Wicklein, 2000; Van Rensburg, Myburgh & Ankiewicz, 1996), then retained in C2005, the rNCS and NCS, and finally merged with Natural Science to form a new learning area.
Natural Science and Technology (DoE, 2011). Pudi (2007) argues that this lack of clarity might have led to many people not being technologically literate “because technological literacy is a concept that lacked explanation and advocacy in the South African situation” (p.41).

The South African Technology curriculum promotes Technology education by the compulsory exposure of all junior learners (Grades 4-9) to the subject Technology. Subsequently, senior learners (Grades 10-12) have the option to specialise in a Technology-related subject, an option that only a small percentage are likely to choose as these subjects are not widely offered in schools. Learners typically only pursue courses related to Technology at the tertiary level again should they have an interest in this area. Consequently, there is a three year gap between most students’ exposure to the subject Technology, having strong implications to whether learners are ready to pursue technology-related courses, like Engineering (Luckay & Collier-Reed, 2011), at tertiary level. Therefore, this study will use a valid and reliable instrument – the Technological Profile Inventory (TPI) (Luckay & Collier-Reed, 2011) – to determine whether learners are technologically literate at the end of their schooling, and if they are, do students have a basic or advanced level of technological literacy upon entering university.

**What it means to be technological literate**

Technology education is enacted in schools through the subject Technology (Lewis, 1999) and many claim that the end-product of technology education is technological literacy (Waetjen, 1993). To assess technological literacy, one must have a clear idea of what it is. However, there is currently not a single umbrella definition of technological literacy, as it varies, depending on the discipline (Gagel, 1995, 1997). Within technology education, there are varying views of technological literacy, some polarised between the process and content camps (Lewis, 1999); functional and school knowledge (Tamir, 1991); and practical competence in technological literacy (Lewis, 1999). A further confounding factor in defining technological literacy is socio-cultural context, where social, cultural, educational and work backgrounds influence ones understanding of technological literacy (Garmire & Pearson, 2006). However, an emerging line of research unifies three major components or dimensions of technological literacy – the three-component model of defining technological literacy. This model 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 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 will be adopted for the purpose of the present study.

For policy-makers, educators and citizens to prioritise technological literacy, a rigorously developed instrument, found to be valid and reliable, is crucial (Garmire & Pearson, 2006). An instrument is the preferred method of determining technological literacy, especially in schools, because one can gauge the present levels of technological literacy of many individuals in a short period of time, given that technology, and thus technological literacy, changes rapidly. This instrument might also give an indication of how effectively schools promote technological literacy and where improvements can be made. But, Garmire & Pearson (2006) examined twenty-eight instruments assessing technological literacy, and found that most instruments tend to focus on attitudes and opinions (for example, L. C. Rose & Dugger Jr, 2002; L. C. Rose, Gallup, Dugger Jr, & Starkweather, 2004), most dimensions were assessed separately, and the dimension, capabilities, which included the design process, was difficult to assess, especially at a large-scale level. Capability is very likely an indication of learner’s ability to use the design process, and people should be able to use the design-thinking process to
identify and solve problems to be technologically literate (Denton & Williams, 1996; Mioduser & Dagan, 2007).

The study of Collier-Reed (2006) provides a strong conceptual base for the development of an instrument, incorporating the three major components of technological literacy. In a previous study, an instrument – the Technological Profile Inventory – was developed and found to be reliable and valid (Luckay & Collier-Reed, 2011). In South Africa, the Technology NCS (2002) uses design to deliver the content of the subject Technology through a functional approach (Pudi, 2007). The functional approach emphasizes the study of design functions (rather than stages), like, a technological process, with the main ideas being: identification and definition, exploration and investigation, decision making, planning, making, and evaluation. The process is agile, where the problem solver may use more than one of the design functions (e.g., investigation and evaluation), depending on the specific context and requirements of the particular stage. Studies on the implementation of the functional approach in the design process suggest that the functional approach is more effective than the structural approach (step-by-step thinking) as it allows students to actively revise their models at each and every stage and make decisions about the next step to be taken, learning becomes a highly constructivist process (Mioduser & Dagan, 2007). This suggests that students in South Africa should have a more than basic level of technological literacy at the end of their schooling.

The Technological Profile Inventory (TPI)

Collier-Reed (2006) interrogated the dimensions of technological literacy through a phenomenographic analysis of interview data and describes five qualitatively different ways of experiencing the nature of technology and four qualitatively different ways of experiencing interacting with technological artefacts. These categories of description are presented in Table 1. We argue that collectively, these dimensions of technological literacy satisfy the core content requirements for what it means to be technologically literate (Collier-Reed, 2006; Collier-Reed, Case & Linder, 2009; Luckay & Collier-Reed, 2011).

In order to be able to classify students relative to these categories, and hence ultimately to be able to describe their technological profile, we developed a series of statements that could be used to interrogate students’ views on these dimensions of technological literacy. It was important when developing the statements to ensure that they were in fact representative of – or attributable to – the categories under consideration.

Table 1: Ways of experiencing the nature of technology and interaction with technological artefacts

<table>
<thead>
<tr>
<th>The nature of technology is conceived of as:</th>
<th>Interaction with technological artefacts is through:</th>
</tr>
</thead>
<tbody>
<tr>
<td>An artefact</td>
<td>Direction</td>
</tr>
<tr>
<td>The application of artefacts</td>
<td>Instruction</td>
</tr>
<tr>
<td>The process of artefact progression</td>
<td>Tinkering</td>
</tr>
<tr>
<td>Using knowledge and skill to develop artefacts</td>
<td>Engaging</td>
</tr>
<tr>
<td>The solution to a problem</td>
<td></td>
</tr>
</tbody>
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In order to ensure this congruence, the interviews that were previously phenomenographically analysed were reanalysed with a focus now on the individual. Consequently, a 41 item pilot instrument emerged from this analysis. The instrument was subjected to wide-scale testing to confirm the validity and reliability of the items (Luckay & Collier-Reed, 2011).

Exploratory analysis of the TPI

Data were collected from 435 students in May of their first year of study at a university in Cape Town. The groups were split between Engineering (198) and Commerce (237) students. Participants were required to supply biographical information in the form of their age, gender, and degree
programme. From this information, it was determined that the sample consisted of 63% males and 36% females, and the average age of the students was 18 years. 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 questionnaire took between 13 and 20 minutes to complete (see Luckay & Collier-Reed, 2011).

The data were imported into SPSS (Field, 2005), a statistical analysis software package, and a factor analysis was conducted, deriving a nine-factor solution which accounted for 52.3% of the variance. Items with a factor loading of less than 0.3, and items whose factor loadings were low, were removed from further analysis. These items were thus of low value in contributing to the overall view of those completing the TPI. The remaining scales were subsequently re-analysed, and a six-factor solution was obtained accounting for 54.5% of the variance.

The factors emerged in line with the categories presented in Table 1 – which was not unanticipated as the items themselves were developed based on a rigorous qualitative analysis of interview data which was in turn informed by categories that emerged from a phenomenographic analysis (Collier-Reed, 2006). These factors were subsequently collectively named in line with the original categories described in Table 1. The factors contain items as follows: Artefact (6 items); Process (6 items); Direction (3 items); Instruction (2 items); Tinkering (3 items); and Engaging (3 items). The eigen values ranged between 1.1 and 3.6. A further index of scale reliability and validity were generated – the Cronbach alpha coefficient – for which the values on the TPI scales ranged between 0.60 and 0.73. Taken together, the results from the factor analysis, as well as the index of scale reliability and validity (the Cronbach alpha reliability index) suggest that the *Technological Profile Inventory* is reliable and valid for use amongst the group that would be targeted as part of an admissions process and can therefore be used with confidence.

We suggest that the Engineering students represent a group who should arguably have a level of technological literacy that is more sophisticated than that of the Commerce students – although the two groups arguably have a similar entry requirement for acceptance to the university. A preliminary analysis of the differences between the Commerce and Engineering students, as highlighted by the revised TPI, was thus undertaken. A one-way between-groups multivariate analysis of variance (MANOVA) (Tabachnick & Fiddell, 2007) was performed to investigate these group differences. Six dependent variables were used, namely, Artefact, Process, Direction, Instruction, Tinkering, and Engaging. The results show that there was a statistically significant difference between the Commerce and Engineering students’ responses to the TPI on the combined set of dependent variables $F(6, 428) = 6.51, p = 0.000$. When the results for the dependent variables were considered separately, there was a statistically significant difference on the scales Artefact, Direction, and Instruction. Closer inspection of the mean scores indicated for each of the three scales, showed that Commerce students showed higher levels of agreement with the statements in the scales Artefact compared to the Engineering students; Direction compared to the Engineering students; and Instruction compared to the Engineering students.

### Generating a profile using TPI

The instrument that was developed from a phenomenographic study with high school students was thus found to be valid and reliable, using factor analysis and Cronbach alpha respectively (Luckay & Collier-Reed, 2011). This instrument can thus be used with confidence to investigate high school students’ level of technological literacy (or, as in the present study, first year university students entering university). The average scores based on the scores of the students’ responses on the Likert scale from 1 to 7 were generated for the group as a whole. From these, it was possible to determine the profile of this group on the dimensions Artefact, Process, Direction, Instruction, Tinkering and Engaging. The profile was generated to see the overall pattern of the group where high scores indicate that the individuals agreed more on a dimension (Figure 1).
On the whole an average student in the sample could be considered to have a reasonable level of technological literacy based on the dimensions in the TPI. In the category ‘Nature of Technology’ (see Table 1) there were however a significant number of students who conceive of technology as a product, a less sophisticated conception of technology. However, the higher levels of agreement in conceiving technology as a Process than rather than an Artefact (see Figure 1) suggests that these students entered their first year university programme with at least a basic level of technological literacy, albeit a level higher than that of an artefact.

In the category ‘Interacting with a Technological Artefact’, students were less likely to want to be directed when interacting with a technological artefact (Direction) because as showed lower levels of agreement on this dimension (see Figure 1). In addition, the higher levels of agreement on the dimensions Tinkering and Engaging also suggest a relatively more advanced level of interacting with technology with the group as a whole.

![Figure 1](image-url)  

Figure 1. Responses on the TPI of average students comprising all 435 students.

If one compares the overall results of the full sample to that of the Engineering students’ scores (shown in Figure 2), then it is specifically in the conception of technology as an artefact and the interaction with a technological artefact through direction that specific differences are highlighted. Although small, these differences have been shown to be statistically significant. In the original development of these categories, Collier-Reed (2006) suggests that when technology is conceived of as an artefact, that:

- technology is described in terms of being some physical, tactile thing. It is characterised as involving artefacts that have particular qualities or features. Artefacts simply exist and people are absent from this conception of technology. The purpose of technology is taken for granted and is not focussed on and neither is the impact of technology focussed on. The character of technology relates to the properties and qualities of artefacts. (p. 100)

Furthermore, he goes on to describe the interaction with a technological artefact is through direction to be as:

- the result of a directive by someone and is not something that happens spontaneously. There is reluctance to make a first move toward approaching an artefact. [Students] are on the outside
looking in towards an artefact as a reified object. Interaction with a technological artefact takes place in a formalised context where pupils are required to respond to the directions of an authority. ... The interaction is characterised by their level of detachment from this interaction. [Students] experience no ownership in their interaction 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 it, as there is a fear of access. Specific directives from an authority figure are required for [students] to overcome their fear of the artefact. (p.101)

From this description it is more likely that the Engineering students would conceive of technology and the interaction with technological artefacts in this way – and this is supported by the data shown in Figure 2.

![Figure 2. Profile of a typical student and an Engineering students’ responses to the TPI.](image)

**Discussion**
In this study, a valid and reliable instrument, the *Technological Profile Inventory* (TPI) (Luckay & Collier-Reed, 2011) was used to indicate how effectively schools promote technological literacy and where improvements can be made. The results, based on the dimensions of the TPI, suggest that students typically have a reasonable level of technological literacy when they arrive at university. This implies that teachers are managing to fulfil the requirements in the NCS in addressing technology education. In the present study, Figures 1 and 2 also indicate that there are a significant number of students who still view technology as primarily being about an artefact and who will only interact with a technological artefact through direction – i.e. by being told that they must.

If being technologically literate encompasses how one conceives and interacts with technology artefacts, then a functional approach aptly describes a person’s literacy levels (Mioduser & Dagan, 2007; Pudi, 2007). The NCS emphasises the technological process through design (Department of Education [DoE], 1997). As the design process similarly encompasses “the process of making (planning and designing), understanding how the technological product can be used beneficially, ethically and responsibly, as well as about understanding systems” (Pudi, 2007) – a cognitive and functional approach – one might similarly argue that a cognitive-function approach can be used to describe the design process.

The results suggest that in the category ‘Nature of Technology’ (see Figure 1) the majority of students
conceived technology as a process, an advanced conception of technology. If this is so, then most of the students are likely to have a deep understanding of the technological process during design. Students were probably taught in a generalised systematic way, starting with an analysis of problem, design of solutions, and evaluation of optimum solution and implementation of the preferred solution (NCS, 2002; Mioduser & Dagan, 2007). As a consequence, they gained an understanding of the technological process, implying that they understand the multitude of decisions required to ensure that the end-product was developed by making (planning and designing), understanding how the technological product can be used beneficially, ethically and responsibly, as well as about understanding systems (Pudi, 2007). Thus most students in the sample have an advanced conception of the ‘Nature of Technology’, but one should be aware there are a fairly high number of students who conceive technology as a product, implying that is these students are enrolled in Engineering programmes, and then this is an indicator that they might fail the course. This result requires further future insight through interviewing the students.

Similarly, in the category ‘Interaction with Technology’ students are more likely to interact with technology at advanced levels. This result suggests that the ‘functional’ part of this cognitive-functional approach is emphasised during teaching at schools – driven by a focus on the practical approach of design and making (Mioduser & Dagan, 2007). McCormick (1997, p. 142) argues that “if technology is to be largely focused on practical aspects of designing and making, then it cannot possibly bear the sole weight of responsibility for enabling students to make sense of technology”. He argues further that technology education involves both practical and intellectual aspects. As to how much practical, theory or intellectual aspects should be catered for in technology education depends on many things, including aims and context. Thus, it might be that the aims of the curriculum and the context that the students were taught the subject Technology, which supported the functional approach, allowed the students to adopt a balanced approach to design.

Interestingly, students in the Engineering classes were not markedly different from the rest of the sample with regard to their levels of technological literacy (see Figure 2), given that these students were carefully selected for the programme through the NSC and NBT. This implies that students’ limited exposure to Technology as a subject in the FET levels is not necessarily advantageous. Students who are not exposed to the subject Technology miss many years of exposure to the subject, and those who might want to enter technical courses at university level need to re-visit their knowledge from Grade 9. On the other hand, those who are not reasonably technologically literate might hamper their success in Engineering programmes or other technical programmes (Luckay & Collier-Reed, 2011).

Thus, teachers drive a balanced view of the technological process in terms of knowledge and skills, and thus drive a deeper understanding of the technological process. They could use the student profiles to adjust and maintain this balance. The questionnaire could give teachers a variety of insights into their teaching. For instance, Collier-Reed (2006) suggested that the less advanced ways of interacting with technology (through Direction and Instruction) requires that teachers provide well-defined and supportive environments to guide students into what is, for them, often a potentially intimidating experience. The goal, in this case, should be to develop the confidence of these pupils in their interaction and take them to the point where they feel confident to initiate interaction with artefacts, even if initially in a limited way. In any structured activity, aspects are included that can promote development and nurturing of what is hoped would be a growing confidence in interacting with a technological artefact. Similarly, those who interact with a technological artefact in a more advanced way (through Tinkering and Engaging) may feel constrained by a detailed, carefully structured, nurturing environment that is so important in the less advanced way of interacting. In contrast students who tinker and engage with technological artefacts are shown through structural aspects to thrive on investigation and exploration. The approach to facilitate this tinkering and engaging would require a different outlook. The challenge is thus to develop structured activities that explicitly recognise that there are various approaches learners could take in their interaction and
makes provision of these.

In conclusion, the study suggests that students in this sample are technologically literate. Moreover, the subject Technology, being taught as a separate subject in the curriculum, seems to be functioning effectively for this group of students. Further future research might give insight in determining teachers’ levels of technological literacy, and what the future holds when the subject Technology is combined with Science.

References


