Exploring First Year Engineering Students' Levels of Technological Literacy at Two Higher Education Institutions in the Western Cape Province, South Africa

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In this study, the technological literacy of students in their first year of an engineering programme within two higher education institution (HEI's) is described, analysed and compared. Furthermore, the study explores the possible influences of socio-economic status (SES) on the technological literacy of engineering students. Drawing on Mitcham's (1994) framework, he describes technological literacy by two interacting components, namely, how one 'thinks' about technology (nature of technology) and how one interacts with technology (interaction with technology), acknowledging the socio-cultural context of an individual, where social, cultural, educational and work backgrounds influence one's understanding of technological literacy. The study used a mixed-method approach applying the sequential use of both quantitative and qualitative data collection. During the quantitative data collection phase, the Technological Inventory Profile (TIP) was used to determine the students' levels of technological literacy. During the qualitative data collection phase (n=2), the profiles of one female student from a high SES and one male student from a low SES background who entered Engineering programmes, were probed. A case study approach was used to determine patterns and trends in their background that shaped their levels of technological literacy. Preliminary findings of the quantitative data using descriptive statistics suggests that students, in general, have a basic level of technological literacy based on the dimensions Artefact, Process, Direction/Instruction, Tinkering and Engagement. However, preliminary results of the qualitative part of the study using interviews with the two Engineering students shows that there is a tentative influence of SES on the participants' technological literacy.
Keywords: Technological literacy, Engineering programme, First year student, Socio-Economic Status Higher Education

Introduction

Entering an engineering programme is a springboard for a wide range of involvements in society. It shows that the student has a good ability in Mathematics and Science, and this is a traditional route into middle class for a bright young teenager from a poor family (Case, 2010). But South African statistics show that students seldom complete the degree. Most students who drop out are from previously disadvantaged backgrounds (Fraser et al., 2011). Consequently, Case (2010) argues that the curriculum should not only be responsive to students' skills, but to the students' knowledge and knowing. This sociological perspective could motivate and increase the number of engineering graduates.

The lack of clarity in defining engineering and technological literacy amplifies the problem of developing and executing the means by which it can be achieved (Krupczak & Blake, 2014). There is a gap in the South African literature on a broad understanding of the skills that our school curricula are equipping the prospective engineering students through the subject Technology. Furthermore, to delve in-depth into what contextual factors that influences these students' performance. Therefore, the purpose of this study is to draw on the perspective of engineering students' skills defined in terms of their

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technological literacy, and then to assess the contextual factors that might influence their technological literacy alongside socio-economic status. The study will address these issues in two research questions, which firstly define levels of technological literacy, and secondly explore contextual factors.

1. To what extent are Engineering students technologically literate in their first year of study?
2. How does the Engineering students' home background, described in terms of their socio-economic status (SES), influence technological literacy?

A Framework for Technological Literacy

Numerous international studies have found that the general population naïvely associates technology with the knowledge of computers (e.g., Bame & Dugger, 1989; Boser *et al.*, 1998; Rose *et al.*, 2004; Garmire & Pearson, 2006), a view shared in local studies (Mapotse, 2012; Mapotse, 2015). This notion of technology is flawed as it is one-dimensional, ignoring the social dimension. A holistic definition of technological literacy comprising two components has been argued to create a fuller picture, as it considers how individuals 'think' about and 'interact with' technology – combining thinking and doing.

The work of Mitcham (1994) describes technological literacy by two interacting components, namely, how one 'thinks' about technology (nature of technology) and how one interacts with technology (interaction with technology), acknowledging the importance of the socio-cultural context. Through these interactions, levels of technological literacy develop. Individuals have different levels of technological literacy – ranging from simplistic to sophisticated. More recently, Collier-Reed (2006) extended the framework of Mitcham (1994) by adding a third component that unifies three major dimensions of technological literacy – the three-component model of defining technological literacy. This model describes an individual's level of technological literacy more holistically, which is argued to develop a holistic perspective of an individuals' technological literacy, and further develops a focus on the essential levels of technological literacy.

The field of technological literacy is broad within a wide range of foci (ITEA, 2000, 2007). The majority of studies in this area focuses on students' engagement with technology (De Vries & Tamir, 1997; DiGironimo, 2011; Michael, 2014). Other smaller focus areas include studies on engineering (Kroes, 2012; Simondon, 2017) and schooling (Dugger, 1995; Ankiewicz et al., 2006; Milne, 2017, Stables, 2017), and fewer studies in higher education. Much research on technology literacy in higher education is presented as state-of-the-art (Ritz, 2011; Dakers et al., 2019), thus this study is focussed on higher education, which represents a gap in the literature.

Methods

The study used a mixed-method approach, applying the sequential use of both quantitative and qualitative data collection. The aim of using this research design is to get detailed information about the phenomenon or to explore the results in detail (Creswell, 2014). During the quantitative data collection phase, the *Technological Inventory Profile* (TIP), a reliable and valid instrument, which was used to determine the students' levels of technological literacy (Luckay & Collier-Reed, 2014).During the qualitative data collection phase (n=2), the profiles of one female student from a high SES and one male student from a low SES background who entered Engineering programmes at two higher education institutions, were probed. These students were chosen because they are argued to represent a 'typical' student in each of the cohorts, at each of the higher education institutions. Moreover, a case study approach was used to determine patterns and trends in their background shaping their levels of technological literacy (Tabachnich & Fiddell, 2007).

During the quantitative data collection phase, the 30-item instrument was administered to two groups of students from two higher education institutions (HEI's). Data were collected from 213 students at higher education institution 1 (HEI1) and 209 students at higher education institution 2 (HEI2). One might argue that there are contextual differences between the two higher education institutions (HEI's), which are remnants of the legacy of Apartheid in South Africa. The two HEI's in the Western Cape Province are argued to be different in their student intake. Moreover, these students come from schools of similar classification, influenced by Apartheid classification of students from a predominantly Black student population and students from a predominantly White student population. Contextually, the two HEI's are different. Beside the difference in student intake, the university that Student 1 attends offers a well-recognised four year degree programme, while Student 2 attends a university of technology and his three year diploma is considered to develop more technically trained students, who will specialise in another one year to receive a technical degree.

Participants were required to supply biographical information in the form of their age, gender, and degree programme and high school attended. From this information, it was determined that the sample in HEI 1 (n = 213) consisted of 99 males and 114 females – all students indicated their gender. The average age of the students was in HEI 1 was 19 years 3 months (range = 19-38 years), all students indicated their age. In HEI 2 (n = 209) the sample consisted of 108 males and 101 females – all students indicated their gender. The average age of the students was in HEI 2 was 20 years 11 months (*SD* = 0.302, range = 17-33 years), 17 people did not indicate their age. The participants were informed that the purpose of the study was to explore their ideas about technology. The questionnaires were administered personally to ensure consistency in the instructions given to the students and to answer possible queries. During the instruction session (which lasted on average 6 minutes), the students were told that completion of the questionnaire was voluntary (no student objected to completing the questionnaire), and that all responses were confidential. Participants were required to mark their level of agreement with each item on a seven-point Likert scale (Cohen, Manion, & Morrison, 2000) on a scale ranging from *Strongly Disagree* to *Strongly Agree*. The questionnaire took between 13 and 20 minutes to complete. The data were analysed using the statistical software package SPSS version 25 using MANOVA described in Luckay and Collier-Reed (2014). The 422 participants were grouped into their two HEI's 1 and 2, as described above.

During the qualitative data collection phase (n=2), the profiles of one female student, aged 18, from a high SES background (Student 1) and one male student, aged 19, from a low SES background (Student 2) who entered Engineering programmes, and were considered to be 'average' students typical of the quantitative cohort analysed, guided by the averages from the questionnaire, were probed. The research employed qualitative analysis using the thematic analysis strategy. The interviews were transcribed into words and with colour variations of red, orange and blue, relevant and salient information was enlisted. The colours were categorized and correlated as major and minor categories that were compared according to their relevance in relation to the aim and the research questions. The major categories were the factual statements or key words from the participants while the minor categories were the supporting statements given to explain the key words. These categories formed the basis for the themes, patterns or concepts with basic similarity features, which were used to find answers to the sub-research questions. According to Neuman (2006), a qualitative analysis organised data into themes, concept patterns of ideas for similar features.

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Results and Discussion

Preliminary findings of the quantitative data using descriptive statistics suggest that students, in general, have a basic level of technological literacy based on the dimensions *Artefact*, *Process*, *Direction/Instruction*, *Tinkering* and *Engagement*. This reult is line line with he findings of Luckay and Collier-Reed (2014). However, preliminary results of the qualitative part of the study using interviews with the two Engineering students, show that there is a tentative influence of SES on the participants' technological literacy.

The results suggest that technological literacy is not a unidimensional construct, and that the sociological element plays a very important role in conceptualising the phenomenon (Case, 2011; Rupnik & Avsec, 2019).

Quantitative Results

The average item means for the dimensions of the questionnaire, namely, Nature of Technology (*Artefact*, *Process*) and Interaction with Technology (*Direction/ Instruction*, *Tinkering* and *Engagement*) were described in Table 1 below. Luckay and Collier-Reed (2014) described each dimension. In the current study, the average item means for each of the two HEIs are recorded in Table 1, for the dimensions *Artefact*, *Process*, *Direction/Instruction*, *Tinkering* and *Engagement*.

In the current paper I will limit the scope to only focus on students' conceptions of technology, which will be on only two dimensions, namely, *Artefact* and *Process*. The other dimensions, while shown in Table 1, are beyond the scope of this paper.

Table 1. The average item class means for the students in the two HEI's - HEI 1, n=213; and HEI 2, n= 209

Conceptions of technology	Dimension	Mean HEI 1	Mean HEI 2
Nature of Technology	Artefact	**2.6623**	**3.5192**
	Process	**4.8873**	**5.2400**
Interaction with Technology	DirectInstr	**3.0163**	**3.4237**
	Tinkering	**5.2426**	**4.6731**
	Engagement	**5.6333**	**5.1186**

In order to address research question 1, I will draw on the data related to the *Nature of Technology* (Artefact and Process). From the results in Table 1, it is evident that a profile of the students' levels of technological literacy indicate that the majority of students conceive of technology simplistically, as and *Artefact*. For the averages of the dimensions at the two HEI's, it is evident that for the scale *Nature of Technology*, which indicates how the students in the two HEI's conceive of technology, the majority of the students in HEI2, the lower SES HEI, conceive of technology more as an *Artefact*, suggesting a less sophisticated conception of technology. For instance, for the item *Technology is a person making something to solve a problem and improve quality of life*, Student 2 disagreed with the statement, while Student 1 agreed, suggesting that they had different theoretical conceptions of technology. While on item 3 *A CD is only technology when you put the CD into a computer and then copy music onto it,* both the students had the same response, they disagreed. Thus from this result it is evident that the two students might have different theoretical perspectives about technology because of their differences in education and SES, but could be in agreement on the practical aspects of the application of a technological tool, which could be because of their similar interest in Engineering. Their levels of difference could be influenced by the sociological perspective (Case, 2010) in their different use of tools (Ingerman & Collier-Reed, 2011).

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Qualitative Results

Given the profiles of students in the quantitative data analysis, two students were selected to represent 'average' or typical students of that cohort in order to further triagulate and probe the quantitative data. I will address research question 2 using these profiles. The demographic data on the questionnaire indicates that the female student [Student 1] attended an elite private school and comes from a family that was generally considered to be from a high SES bracket in South Africa. She is studying toward a mechanical engineering degree programme. Interviews reveal that her mother was also an engineer and her father was an executive. The male student [Student 2] attended a poor school in a township area where the majority of people were considered to be from a low SES background. He is studying civil engineering and will receive a diploma on completion of the three year programme. He did not live with his parents growing up, but his family members, especially his uncle, inspired him to enter an engineering programme. However, his uncle had dropped out in his first year of study. Student 2 felt it was his dream to complete the programme, unlike his uncle's situation. The student claimed that just like his uncle before him, he had financial problems and struggled to pay the university fees.

After analysing the transcribed data, a coding pattern emerged. This process involved three main steps, namely: (1) sifting through data, (2) finding out re-occurring statements or words relevant to the study and (3) classifying into themes. As part of the process, the course of classifying segments of data with message, expressive words are referred to as coding (Johnson & Christensen, 2008). The categories of themes as presented below are:

(1) Technological perspectives (self motivation, prior experiences and inspiration)

(2) Experiences and exposures (Parental influence, financial capability)

In the section below, the themes will be briefly discussed as they relate to the major and minor themes in each table, based on the responses of the interviewees.

Further probing through the qualitative results suggests that the students' conception of technology is influenced by their experiences throughout their life journeys. The key themes of the present study highlights the relevance of social context in techonological literacy, an aspect emphasized in the work of Mitcham (1994). The major themes, namely, self motivation, prior experiences and inspiration suggests that the technology literacy of participants is based on their understanding and knowledge of technology as it is applicable to them. The views of the participants on technology are seen from their personal definition and explanation given below.

> For me technology was something that can make life easier for you it's like if you want to do something very quickly, you don't have to go the long (Student 2)
>
> Technology is like seeing an issue and trying to think of a way to solve it probably some flash of inspiration someone had before they went to sleep. (Student 1)

Another factor driving their levels of technological literacy is their self-motivation, influencing attitude (Rupnik & Stanislav, 2019). The technological literacy of the participants suggests that the knowledge acquired from the high schools influenced their technological literacy. These knowledges act as a background or foundational knowledge guiding the understanding of the participants to conceptually understand technology, which seem to be limited, and might explain the inadequate conception of technology as an *Artefact*:

> Nothing much in primary school until prep school, I think we did one or two experiments is kindling using a magnifying glass to set fire to the paper to make a fire to cook. (Student 1)

> The subjects that I liked it was maths and natural science and I can't remember all of the subjects, but there were some things that I didn't like the most it was social sciences it was just to do with history and stuff and I didn't like that subject and arts and culture I didn't like that subject. I think it is those that I can remember now. (Student 2)

Furthermore, for the averages of scale *Interaction with Technology*, it is evident that the students in the low SES HEI 2 (mean = 5.2426) tinkers and manipulates less with technology that those in the high SES context (mean = 4.6731). For instance, for the item 4 *I always ask permission before I use some new technological thing in case I break it*, it was evident that Student 2 agreed while Student 1 disagreed. This result suggests that Student 2 was careful about their engagement with a technological tool as it might break if they manipulated or tinkered with it. This has implications on their educational learning, that is, their ability to take the technological tool apart and learn from it (Ingerman & Collier-Reed, 2011; Luckay & Collier-Reed, 2014, Doyle et al., 2019). The extent of technological literacy of the participants in line with the major and minor categories is based on their inquisitiveness, coupled with their interest to learn more, and the challenge of finding solutions to their curiosity. This has helped to their understanding of the technology as seen in their response below:

> With inquisitiveness, I opened things up, simple things like toys, I would like sort of roll it around see how the wheels spin look at them from different angles and then eventually probably take like see how we open up. I have broken a couple of pens actually. (Student 1)

Given that Student 2 grew up with less financial stability, it might be that this student was more careful to open up technological tools unless they were broken. Indeed the student did open up tools, but only with permission.

> If it is not working yes I will try to open it but I will ask permission because I have opened so many things like the cables and stoves that are not working I just wanted to see what is inside. For me it is just an experiment of what is going on. (Student 2)

This students' family background typically influenced his decisions, as is evident from the response below. But it is evident that he still tinkered with technological tools, albeit with caution, very likely displaying his engineering interest like Student 1.

> For me I had three choices to make. I applied for mechatronics, electric and civil. So now I chose civil but the thing I have passion but I didn't want to do the same thing my uncle did, so I was afraid of him in those I think, I was afraid of failing so I then I chose to go to civil engineering and when I came here things were (Student 2)

Parental influence is powerful to change the direction of a child and what a child can become in life. Parents are sources of inspiration that can guide and move a child to act and accept a kind of behaviour. In addition, the students' choice of career may be influenced by the financial capacity of the parents together with the personal interest of the students as seen in below responses. **Student 1** *I think I was just kind of assuming that I would study further … My mom and my maths teachers met in parent/teachers meeting there they spend the rest of the time talking about how I should do engineering*

> What inspired me is my uncle he was here at this university doing electrical engineering but he dropped out in the second year because of financial situations so what inspired me is that now I have to come study also and I don't want to be a drop out as he did, so I wanted to pass very well and get what I want in life (Student 3)

Given the results, and in answering the research questions, it is evident that the students' level of technolgical literacy in general, is better classified as *Artefact*, which is a basic level of technological literacy, with HEI 2 being less sophisticated than that of HEI 1. It is evident from the qualitative data that there is an SES influence which impacts the students' ways of thinking and engaging with technology.

Conclusion

Evidence from the current study suggests that students in their first year of study have a basic level of technological literacy, and furthermore, preliminary evidence suggests a social influence, supporting previous studies (e.g., Luckay & Collier-Reed, 2014). Only promoting technological literacy as knowledge is likely to result in students (whether in a high or low SESs) developing a simplistic conception of, and interaction with, technology. Notwithstanding, the school curriculum sets out standards for technological literacy as pre-defined outcomes, as articulated in the ITEA (2000, 2007) standards for technological literacy. Promoting only standards can be detached from the lives of the individuals who develop technological literacy.

Shifting the focus of technological literacy to that of a human endeavour would divert the focus towards technology and technological literacy as a process. This perspective stretches far beyond an understanding of technology as an end-product with a focus on the artefact. One must be able to take into account the human relations with technologies (Dakers 2006; Ingerman & Collier-Reed 2011), emphasising the social influence to shaping students' technological literacy. This is of particular importance in programmes like Engineering. Thus, curricula and policy shifts need to be considered in the shaping of technological literacy both at schools and university (Doyle et al., 2019), and further research would give insight into this.

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