COMPARING THE TECHNOLOGICAL LITERACY OF PRE-SERVICE TEACHERS AND SECONDARY SCHOOL STUDENTS IN SOUTH AFRICA

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Abstract

Technology education was introduced for the first time after the abolition of Apartheid in South Africa in 1994. The technology curriculum required that students become technologically literate. However, in order for students to become technologically literate, teachers need to be technologically literate. In this study we explore pre-service teachers' levels of technological literacy.

The study will draw on an instrument to determine both the pre-service teachers' (n = 12) and secondary school students' (n = 179) levels of technological literacy. The instrument was developed and found to be reliable and valid in previous pilot studies. 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 the university graduated pre-service teachers, and from a unique group of secondary school students who are academically strong as they were selected to enter the Exposition for Science. Profiles of teachers' and students' scores were generated in two categories, namely how they conceive technology (*Conception of Technology*) and how they interact with technology (*Interaction with technology*). The category *Conception of Technology*, are described by two dimensions, namely *Artefact* and *Process*. The category *Interaction with Technology*, are described by four dimensions, namely, *Direction*, *Instruction*, *Tinkering* and *Engaging*.

The outcome of the analysis suggests that pre-service teachers appear to place primacy on technology being associated with an artefact rather than a process. It is thus likely that the pre-service teachers in the present sample teachers will struggle to help school students develop a level of technological literacy that encompasses technology as being more than simply an artefact.

Keywords: Technology, technology literacy, phenomenography, engineering education, pre-service teachers, secondary school students.

1 INTRODUCTION

The introduction of the new curriculum in South African education [1], promote students' understanding of the technological process. The goal is for students to adopt the skills, values, knowledge and attitudes to become critical and creative thinkers, notwithstanding that teachers themselves should be critical and creative thinkers [2].

One might argue that current South African pre-service teachers entering one year post-degree teaching programmes are under-prepared to teach technology education to school students. Typically, a South African students' formal technology education starts from Grades 4 to 9, thereafter most students have a three-year gap between high school and tertiary level technology-based studies, resulting in some students encountering technologically-focussed programmes only at tertiary level [1]. Likewise, pre-service teachers have a similar profile, but many, especially students who are not studying Science or Engineering, only resume their formal technology education during their pre-service teaching programme. Consequently, they are formally technologically-trained up to Grade 9, and might be under-prepared to teach students who are formally trained to Grades 10 to 12.

In order to explore whether pre-service teachers have more sophisticated levels of technological literacy than the students that they will teach, it was necessary to accurately determine just what these levels are at the individual teacher and student levels, by using a valid and reliable instrument. The study would make an important contribution toward determining whether teachers' and students' levels

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of technological literacy are congruent, which could inform teacher training programmes and high school curriculum development.

2 CREATING A LEARNING ENVIRONMENT TO SUPPORT TECHNOLOGICAL LITERACY

South African pre-service student teachers entering post-degree one year teaching programmes have a minimum of ten to fifteen years of experience as pupils, so should be prepared to teach at school. Their experiences are likely to influence their own teaching. They develop their own implicit theories [3] on entering a programme, and are exposed to academic theories or 'expert theories' during the programme [4]. Ideally, if a student accepts the explicit theories, they are likely to grow, however, if there is cognitive dissonance [4, 5], this might have an impact on their development as teachers.

Teachers are influenced by context, and the curriculum sets boundaries to their teaching. If they experience cognitive dissonance [5], then they will tend to rely on context to guide their teaching decisions. Indeed, context can shift the implicit theories [3]. For instance, a pre-service teacher educated through a behaviourist tradition, which is also practiced at the placement school while studying, is likely to hold on to their implicit theory – even though they were exposed to 'expert theories' in their lectures at university. Similarly, a pre-service teacher might hold on to their constructivist implicit theories. Consequently, these teachers are likely to teach students in the way that they were taught [4]. Thus the role of the teacher is crucial to the creativity and motivation of the students.

International studies [6, 7, 8] have found that most curricula adopt social constructivism because it influences motivation and creativity. The concept social constructivism is well developed in the field of science education [9, 10, 11], but is starting to make inroads into technology education [12]. However, the innovation is showing minimal outcomes in practice, especially in technology classrooms [13, 14]. Recently [15] developed a framework to guide a social constructivist learning environments in South African schools - a framework that might be applied in pre-service teacher training programmes in technology education. Ideally, in a social constructivist learning environment, emphasis should be put on a student developing a concept through conceptual change [16]. In such a setting, the teachers' role is to guide students toward cognitive conflict by allowing them to engage actively with knowledge, leading them to question the correctness of their ideas, toward uncertainty, then curiosity, and consequently letting them find answers through investigation [7, 8]. Furthermore, students should be encouraged to gain co-operative skills [7, 8] through approaches like collaboration [17], hands-on activity [18], making knowledge personally relevant [19], investigations [20] and encouraging approaches for students to respect each others' views. In addition, teachers themselves should have mastered the knowledge and processes that they are trying to teach. If not, then they might be unable to assist students in attaining deep conceptual understanding [21, 22]. Teachers who are unable to assist students with conceptual understanding are further challenged when facing classes with a lack of practical resources, and students who lack the foundational skills learnt in prior grades. Overall, teachers play a pivotal role in guiding the transformation of their classrooms to promote problem-solving, and thus a social constructivist learning environment.

Additionally [16] contend that teachers need guidance to implement conceptual change, and derived four significant steps for conceptual change: ideas, metacognition, status and justification. In a classroom where conceptual change guides the construction of knowledge, [23] claims that metacognition stands out as crucial to the conceptual change process. In particular, teachers should guide students to recognise their ideas, evaluate them, and reconstruct ideas based on their dissatisfaction or fruitlessness of an idea. In short, they monitor, integrate and extend their own learning - part of good learning behaviours [23, 24]. On the whole, the structuring of technology classrooms from differing implicit-theoretical stances will have important implications for achievement [3]. Whereas environments that have been structured to fostering collaboration have been found to result in academic success [25] the fostering of a competitive ethos have been found to reduce intrinsic motivation and creativity [26].

One might argue that a good framework guides teachers' success in classroom practice, but the positioning of technology education in the curriculum largely influences how seriously teachers will follow the framework in classroom practice. If technology education is considered to be a vocational subject, for less academic pupils, who are taught skills to produce an artefact without understanding the technological process, then teachers are likely to teach with varying degrees of meaningfulness and authenticity [3]. Likewise, students will react in a similar manner. On the other hand, if technology education is viewed as entitlement – about ensuring that all students become technologically literate – teachers will focus less on the development of a product – and more on debate and discussion to guide students to conceptually develop ideas and focus on the technological process, and being critical as well as ethical about the artifact students develop.

2.1 An Inventory to Profile Technological Literacy

In previous work Collier-Reed [27] interrogated the dimensions of technological literacy and after a phenomenographic analysis of interview data described five qualitatively different ways of experiencing the 'nature of technology' and four qualitatively different ways of experiencing 'interacting with technological artefacts'. The work is further described and developed ([28], [29], & [30]). These categories of description are presented in Table 1.

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

The nature of technology is conceived of as:	Interaction with technological artefacts is through:
An artefact	Direction
The application of artefacts	Instruction
The process of artefact progression	Tinkering
Using knowledge and skill to develop artefacts	Engaging
The solution to a problem	

We argue that collectively, these dimensions of technological literacy satisfy the core content requirements for what it means to be technologically literate [27, 28, & 30]. In order to be able to classify students relative to these categories, and hence ultimately to be able to describe their technological profile, a series of statements were developed, that could be used to interrogate students' views on the dimensions of technological literacy. It was important the statements were in fact representative of – or attributable to – the categories under consideration (see, for example, [28]).

In order to ensure this congruence, the interviews that were previously phenomenographically analysed were reanalysed with the 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, resulting in a 23-item questionnaire, which was expanded to a 30-item questionnaire with the aim of strengthening some of the factors [28]. The 30-item revised TPI questionnaire is the subject of the present study.

3 METHODOLOGY

Data were collected from a combination of 191 high school and pre-service teachers studying at university. The total sample was divided between high school students (179 students – Grades 9 to 11) and pre-service teachers in a one year diploma course to become a teacher at the University of Cape Town (UCT). The high school students were drawn from a unique group - those who participated in a Science Exposition, an annual competition where science- and technology-based projects are displayed. On the whole, these students are considered to be innovative and academically strong in subjects like Science. Similarly, UCT is considered to be the best university in Africa and thus students who enter this university are considered to be good academic candidates. The pre-service teachers come from a variety of academic degree backgrounds, ranging from with only one students from a Science background and the rest Arts and Social Science graduates. These teachers are required to teach students in primary school to upper secondary schools, however, as there is a shortage of technology teachers, many of them end up teaching in upper secondary schools.

Participants were required to supply biographical information in the form of their age, gender, degree programme and grade at school. From this information, it was determined that the sample consisted of 95 males and 78 females for the high school students – 6 did not indicate their gender. The average age of the students was 16 years, with 19 students who did not indicate their age. For the pre-service teachers the sample consisted of 2 males and 10 females – all indicated their gender. The average age of the pre-service teachers was 24 years with all teachers students indicating their age.

The participants were informed that the purpose of the study was to explore their ideas and experiences about technology. The questionnaires were administered personally to the pre-service university student teachers to ensure consistency in the instructions given to the students and to answer possible queries. During the instruction session, the students were told that completion of the questionnaire was voluntary and that all responses were confidential. The school students, on the other hand, required signed parental consent before completing the questionnaire. Thus, they took the questionnaire home to their parents who provided consent allowing the students to decide whether they were prepared to complete it. The parents were able to guide the students through the instructions if required. The response rate for this group of students was 69%, while for the university students were 80%.

Participants were required to mark on a seven-point Likert scale [31] 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.

In order to find differences between the Science Exposition School students and the pre-service university students, as highlighted by the revised TPI, a one-way between-groups multivariate analysis of variance (MANOVA) was performed to investigate group differences. Five dependent variables were used, namely, *Artefact*, *Process*, *Direction/Instruction*, *Tinkering* and *Engaging*.

4 RESULTS

4.1 Cohort analysis based on TPI data

In previous studies [29, 30], the instrument was found to be valid and reliable using factor analysis and Cronbach alpha reliability testing. Further analysis of the data using a MANOVA and comparing a variety of groups of first year university students on the dimensions *Artefact*, *Process*, *Direction/ Instruction*, *Tinkering*, and *Engaging* suggests that the questionnaire is able to distinguish groups of students. Similarly, in the present study, a one-way between-groups multivariate analysis of variance (MANOVA) was performed to investigate group differences between the pre-service university teachers in training and the Science Exposition secondary school students. Five dependent variables were used, namely, *Artefact*, *Process*, *Direction/ Instruction*, *Tinkering*, and *Engaging*. The results are shown in Table 2 below.

Table 2 Differences in responses of the pre-service teachers and students using a MANOVA

Dimension	**Pre-service teacher**			**School**			**Difference**	
	M	*SD*	*n*	*M*	*SD*	*n*	*F*	*p*
Artefact	3.3	1.6	12	2.54	1.2	179	4.41	0.037*
Process	4.8	0.4	12	4.7	0.7	179	0.45	0.502
Direction/ Instruction	3.3	0.9	12	3.2	1.1	179	0.11	0.736
Tinkering	5.1	0.9	12	5.1	1.1	179	0.00	0.984
Engaging	5.6	0.8	12	5.1	0.9	179	3.11	0.079

* $p<0.05$ The sample consisted of 191 respondents.

The results show that there was no statistically significant difference between the group responses (pre-service teachers and school student's) to the TPI on the combined set of dependent variables F (5, 185) = 1.66, p = 0.146. From this result it can be concluded that the groups have no statistically significant differences in the levels of technological literacy.

When the results for the dependent variables were considered separately using a one-way analysis of variance (ANOVA), there was a statistically significant difference only on the scale *Artefact* (Table 2). However, there was no statistically significant differences on all other dimensions, namely, *Process* , *Direction/Instruction*, *Tinkering* and *Engaging* (Table 2). Closer inspection of the mean scores indicated that for the dimension *Artefact*, the Pre-service teachers (M = 3.3, SD = 1.6) showed higher levels of agreement with the statements than the School students (M = 2.5, SD = 1.2). On the other hand, for the rest of the dimensions, the results were similar, namely, *Direction/Instruction* [Pre-service teachers (*M* = 3.3, *SD* = 0.9) and School students (*M* = 3.2, *SD* = 1.1)]; *Tinkering* [Pre-service teachers (*M* = 5.1, *SD* = 0.9) and School students (*M* = 5.1, *SD* = 1.1)] and *Engaging* [Pre-service teachers (*M* = 5.6, *SD* = 0.8) and School students (*M* = 5.1, *SD* = 0.9)] .

5 DISCUSSION

The results from the present study suggest that the pre-service teachers' and Science Exposition school students' levels of technological literacy are similar, attested by the one-way MANOVA in Table 2. There was no significant difference for four of the five scales (*Process*, *Direction/Instruction*, *Tinkering* and *Engaging*) (Table 2). For the scale *Artefact*, the pre-service teachers scored the highest implying that they tend to agree more with the less advanced conception in the category the 'nature of technology' (Table 2). This implies that the pre-service teachers are more likely to conceptualise technology as an *Artefact* and that their level of technological literacy on this dimension is lower level than the school students. This has implications for the teachers themselves, and teacher training.

First, teachers themselves should be creative and critical thinkers [2] to guide students to engage with technological knowledge and interact with technology at higher levels. The sample of teachers in this study has a similar level of technological literacy to the students (Table 2). Given the high school students were a self-selected group with arguably a unique 'technological' profile, which was likely to be higher than an average student. However, the teachers should have higher levels of exposure to technology (a continuous learning chain in their education from primary to tertiary education), and thus higher levels of technological literacy for all the dimensions in Table 2. As this is not evident, and the fact that these pre-service teachers appear to place primacy on technology being associated with an artefact rather than a process, it is likely that the pre-service teachers in this sample will struggle to help school students develop a level of technological literacy that encompasses technology as being more than simply an artefact.

Furthermore, those pre-service teachers who conceptualise technology as an *Artefact* are likely to structure their technology classrooms for less academic pupils (vocational training), with less focus on meaningfulness and authenticity [3], and thus producing students who also conceptualise technology as an *Artefact*. These have implications for the present sample of students, which are at similar levels of technological literacy as the teachers. These students could be stunted in their growth to higher levels of technological literacy. Moreover, they are unlikely to practice the conceptual skills required for conceptual change, preventing them from using metacognition [23, 24] in their thinking. These obstacles in their thinking about, and interaction with, technological artefacts, might demotivate them, and inhibit their future growth in careers like Engineering. In fact, in a previous South African study, [29] found that this group of students had similar levels of technological literacy to a select group of students entering a first year university Engineering programme – which implies that they might be the future group of university Engineering students, which is pivotal to the growth of the profession as there is a shortage of Engineers in South Africa. But further future research is required with a larger and more diverse group of students and teachers.

Second, in teacher training programmes, teacher selection [3] criteria to teach technology should be reviewed. The data in this sample shows that the majority of pre-service teachers have Arts and Social Science degrees (only one teacher had a Science degree). In the study of [28] also compared the technological literacy of the Science Exposition students to, namely, Arts students entering their first year of university study, and found that the Science Exposition students had higher levels of technological literacy on most scales than the Arts students, but lower than the Engineering students. This suggests that perhaps teachers with an Engineering and Science background may possibly be better suited to cope with the demands of advanced students - like those who take part in Science Expositions. In order to teach technology at school, part of a pre-service teachers training should be to develop a more advanced understanding of just what technology is and what it means to be technologically literate.

Third, and following on from the argument above, teacher training programmes should expose students to a variety of theories of teaching, and contexts while teaching and thus one year teaching programmes that have a specialised technology education course are necessary. Being exposed in this way is likely to improve their pedagogy. A better trained teacher is likely to have a wealth of resources to draw on during teaching, and confidence to create problem-solving social constructivist learning environments [7, 8]. They would also help students develop skills related to self-regulation [25] and metacognition [23, 24] - to help students to 'think about their thinking' – a quality essential to the design process – qualities optimised through discussion in groups. Importantly, teachers need to grow themselves by testing their implicit theories. Teachers hold implicit theories [4], influenced by their own experiences when they were taught at school. These theories influence how they will teach. New teachers need to challenge their implicit theories through cognitive dissonance [4]. Indeed, an inspiring lecturer exposing them to a variety of pedagogies, and teaching contexts to challenge them to think outside their comfort zone - would guide the pre-service teachers to think about ways to best create a supportive environment for learning. Thus, high quality training is essential to developing better quality teachers of technology education.

Last, the merging of Science and Technology in the South African school Technology curriculum, implies that positioning Science with Technology as the face of technology education would require teachers to have mathematical and science backgrounds. Many [e.g., 3] claim that the technology and engineering are connected, and thus associating technology with high-value fields (as opposed to vocational) would make technology more appealing to high school students at all ability levels. But, Science teachers should be aware that mutually beneficial partnerships can occur if they support other subjects, like the Arts, and vice versa, as all subjects can make a unique contribution to technology education. Partnerships should be demonstrated clearly, with each party making meaningful contributions to avoid superfluous teaching [4]. Within this new curriculum paradigm, technology should never be allowed to become seen by students as simply applied science.

6 CONCLUDING COMMENTS

The article had the objective of determining South African teachers' levels of technological literacy. This study uses a small representative sample of South African pre-service teachers to determine what they know and can do with regard to technology. Findings from this study would be essential to provide valuable insights into how well new teachers are being prepared to think technologically, and to improve technological literacy of both teachers and students.

The outcome of the analysis suggests that the present sample of pre-service teachers are unlikely to be able to make a significant contribution to the development of school students' development of advanced conceptions of technological literacy.

The next stage in this project, drawing on a larger sample of teachers, is to find descriptions that might constitute minimum, adequate and exemplary technological literacy for these teachers. These could be determined through categorising the responses into bands or groups, preferably setting some standards by experts in the field. A framework or guideline could ultimately be developed that could help in the training of teachers to a level that would make the biggest impact on the development of the technological literacy of our youth.

REFERENCES

[1] Department of Education, 2002. Revised National Curriculum Statement Grades R-9. Technology. Pretoria: Government Printers.

[2] Pudi, T.I. (2007). Understanding technology education from a South African perspective. Pretoria: Van Schaik.

[3] Dow, W. (2006). Implicit theories. In Drakers (Ed). Defining Technological Literacy. New York: Palgrave Macmillan.

[4] Dakers, J. R. (2006). Defining technological literacy. New York: Palgrave Macmillan.

[5] Festinger, L. (1957). A theory of cognitive dissonance. Stanford, CA: Stanford University Press.

[6] Taylor, P. C., Fraser, B.J., & Fisher, D. (1997). Monitoring constructivist learning environments. International Journal of Educational Research, 27, 293-302.

[7] Johnson, D. W., & Johnson, R. T. (2007). Creative constructive controversy: Intellectual challenge in the classroom (4th ed.). Edina, MN: Interaction Book Company.

[8] Johnson, D. W., & Johnson, R. T. (2009). Energizing learning: The instructional power of conflict. Educational Researcher, 38(1), 37-51.

[9] Driver, R., & Oldham, V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education, 13, 105-122.

[10] Driver, R., Asoko, H., Leach, J. Mortimer, E., Scott, P. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 23(7), 5-12.

[11] Fosnot, C. T. (1996). Teachers construct constructivism. In C. T. Fosnot (Ed.), Constructivism: Theories, perspectives, and practice (pp. 205-216). New York: Teachers College Press.

[12] Garmire, E. & Pearson, G. (2006). Tech tally: Approaches to assessing technological literacy. Washington D.C.: National Academies Press.

[13] Dakers, J. (2005). Technology education in Scotland. An investigation of the past twenty years: In Marc de Vries (ed) (2005). PATT-15 Pupils' Attitude Toward Technology. International conference on design and technology available on http://www.iteawww.org/D4c.html

[14] Volk, K. (2005). The rhetoric and reality of technology education in Hong Kong. PATT-15 Pupils' Attitude Toward Technology. International conference on design and technology available http://www.iteawww.org

[15] Luckay, M.B. (2010). Implementation of social constructivist learning environmentsin grade 9 Natural Science in the Western Cape Province, South Africa. Unpublished doctoral thesis, University of Cape Town, South Africa.

[16] Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In B. J. Fraser & K. G. Tobin (Eds.), International Handbook of Science Education (pp. 199-218). Dordrecht, The Netherlands: Kluwer Academic Publishers.

[17] Mayer, R. E. (1998). Cognitive theory for education – what teachers should know. In N. M. Lambert & B. L. McCombs (Eds.), How students learn – reforming schools through learner-centred education (pp. 353-379). Washington D.C: American Psychological Association.

[18] Lebow, D. (1993). Constructivist values for systems design: Five principles toward a new mindset. Educational Technology Research and Development, 41(3), 4-16.

[19] Stears, M., & Malcolm, C. (2005). Learners and teachers as co-designers of relevant science curricula. Perspectives in Education, 23, 21-30.

[20] Dunlap, J. C. (1999). Rich environments for active learning on the web: Guidelines and examples. Paper presented at the Proceedings of WebNet 99 – world conference on www and internet, Charlottesville, VA.

[21] Beeby, C. E. (1966). The quality of education in developing countries. Cambridge, MA: Harvard University Press.

[22] Fiske, E. B., &, & Ladd, H. F. (2004). Elusive equity: Education reform in post-apartheid South Africa. Washington, D.C.: Brookings Institution Press.

[23] Gunstone, R. F. (1994). The importance of specific science content in the enhancement of metacognition. In P. Fensham, R. Gunstone & R. White (Eds.), The content of science: A constructivist approach to its teaching and learning (pp. 131-146). London: Falmer Press.

[24] Gunstone, R. F., & Northfield, J. (1992). Conceptual change in teacher education: The centrality of metacognition. Paper presented at the American Educational Research Association, San Francisco, CA.

[25] Slavin, R. E. (1994). Educational psychology: Theory and practice. Boston: Allyn & Bacon.

[26] Ryan, R. & Deci, E. (2000). When rewards compete with nature: the undermining of intrinsic motivation and self regulation. In C. Sansone and J. Harackiewicz (eds), Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance. New York: Academic Press.

[27] Collier-Reed, B. I. (2006). Pupils' experiences of technology: Exploring dimensions of technological literacy. Unpublished PhD. University of Cape Town.

[28] Luckay, M.B., & Collier-Reed, B. (2011). Admitting students with the best chance of success: Technological literacy and the Technological Profile Inventory. Proceedings of the South African Society for Engineering Education. University of Stellenbosch, Cape Town, South Africa. August 2011.

[29] Luckay, M.B., & Collier-Reed, B. (2011). The development and validation of an instrument – the Technological Profile Inventory – to determine students' level of technological literacy in South Africa. Proceedings of the 5th International Conference of Education Research and Innovation. Madrid, Spain 14-16 November 2011.

[30] Luckay, M.B., & Collier-Reed, B. (2012). Technological Profile Inventory : Determining first year university students' technological literacy. Proceedings of the South African Association of Research in Mathematics, Science and Technology Education, Lilongwe, Malawi 16-19 January 2012.

[31] Cohen, L., Manion, L., & Morrison, K. (2000). Research methods in education (5th ed.). London, New York: Routledge Falmer.