Developing the Professional Knowledge of Technology Student Teachers via a Parallel Approach: A Longitudinal Study

Rina Grobler, University of Johannesburg, South Africa
rinag@uj.ac.za
Piet Ankiewicz, University of Johannesburg, South Africa
pieta@uj.ac.za

ABSTRACT

In a small scale, four-year longitudinal, quasi-experimental research project, technology student teachers could study the school subject in parallel, together with the development of discipline knowledge (or their major) within the broader development of their pedagogical content knowledge (PCK). We investigated the performance of students – who had studied the school subject at school and those who studied it in a postschool-university context – in their (1) major, (2) specialised methodology/ pedagogy and (3) their experiences and competencies during their final year work-integrated learning period in schools. We interpreted the findings within the broader theoretical framework of Shulman's PCK by relating the first aspect to content knowledge, and the second aspect to pedagogical knowledge. We found that the parallel approach to PCK development in technology teacher education seems to be viable to increase the number of prospective technology student teachers, with the requirement that it happens within a social constructivist, co-operative learning environment with ample opportunities for cognitive and practical apprenticeship in a community of practice. However, by building on Shulman's PCK and Gardner's cognitive theory, Banks has developed the internationally acknowledged model of teacher professional knowledge (TPK). It entails the active interaction between subject knowledge, school knowledge, pedagogical knowledge and experience which underpins the personal subject construct of the teacher. The purpose of this conceptual paper is to reinterpret the previous findings through the lens of Banks' TPK model by following a qualitative meta-synthesis as research methodology. In conclusion, implications for curriculum design of initial professional education of technology teachers are drawn.

Key Words: Technology education, Technology teacher education, Pedagogical content knowledge (PCK), Teacher professional knowledge (TPK)

1. INTRODUCTION

Universities in South Africa and in various other countries play an important role in the education of technology teachers (Ankiewicz, 2021). Despite technology subjects being labelled as priority subjects in South African schools, extremely low numbers of students have enrolled for these subjects over the past few years, and also at the university where the research was conducted (Ankiewicz, 2018; Grobler, 2018). To combat the trend of decreasing enrolment numbers for the four-year BEd degree in technology education, students who did not study the school subject Engineering Graphics and Design (EGD) at school could study it at university in parallel with their major, Engineering Graphics and Technology Education (EGTE). This is a novel idea as it is usually assumed that students' majors are built on qualifications gained earlier in their education. During the first three years of study, some of the students had to take the school subject EGD and the majors (subject knowledge) simultaneously to develop their pedagogical content knowledge (PCK). The school subject also served as a base for their parallel PCK development (Grobler & Ankiewicz, 2022a). To better accommodate students who did not have EGD in Year 12, the pedagogical practices were reconsidered to provide more intensive support to these students (Grobler & Ankiewicz, 2022a). This was done, inter alia, by assigning a double period per week during their first and second year of study for practical apprenticeship for Year 10–12 EGD (Grobler & Ankiewicz, 2022b). This was facilitated by an expert, who was a schoolteacher, and who was appointed as a tutor and provided guidance in a peer-based collaborative learning environment (Jakovljevic & Ankiewicz, 2016). During their second year of study, an additional expert was appointed as a tutor assistant to provide individual attention during tutorials and consultation times to assist the students to cope better with the school subject (Grobler & Ankiewicz, 2022b). At the end of the second year the assistance of the tutorials, tutor and tutor assistant was terminated and from there on the students had to take full responsibility for their own learning.

The findings of this longitudinal study were reported at different stages of its development during the past five years (Grobler, 2018, 2019; Grobler & Ankiewicz, 2021, 2022a, 2022b). A comprehensive report on (*The) the viability of diverting from a linear to a parallel approach to the development of PCK in technology teacher education* was compiled by Grobler and Ankiewicz (2022a). The findings were interpreted within the broader theoretical framework of Shulman's (1986, 1987) PCK by relating students' performances in their major to content knowledge, and their experiences and competencies during their Work Integrated Learning (WIL) to pedagogical knowledge. We found that the parallel approach to PCK development in technology teacher education seems to be viable to increase the number of prospective technology student teachers, because more students get the possibility of enrolling even though they did not study EGD in Year 12. The requirement is that it happens within a social constructivist, co-operative learning environment with ample opportunities for cognitive and practical apprenticeship in a community of practice. However, by building on Shulman's (1986, 1987) PCK and Gardner's (1983) cognitive theory, Banks (1996) developed the internationally acknowledged model of teacher professional knowledge (TPK). This model entails the active interaction between subject knowledge, school knowledge, pedagogical knowledge and experience which underpins the personal subject construct of the teacher. It seems that Banks' TPK model holds affordances for our previous study. The purpose of this conceptional paper is to reinterpret the previous findings of our study through the lens of Banks' TPK model through a qualitative meta-synthesis as research methodology.

2. BANKS' MODEL FOR CONCEPTUALISING TEACHER PROFESSIONAL KNOWLEDGE

2.1. Foundations of Banks' model for teacher professional knowledge

Banks et al. (2004), as part of the 'DEPTH' study, presented a graphic framework (Figure 1) that helped to visualise the dynamic relationship between the types of knowledge implied by the diagram. This framework is not a Venn diagram, but it illustrates the three overlapping spheres which represent school knowledge, subject knowledge, and pedagogical knowledge respectively and a rectangle over the overlapping areas of the spheres form the teacher's personal subject construct or professional knowledge (Banks, 2022). Therefore, a teacher's personal subject construct comprises a combination of school knowledge, subject knowledge and pedagogical knowledge supporting each other. Furthermore, Banks et al. (2004) stated that a teacher's subject knowledge is enhanced by his or her own pedagogy in practice and by the contextual expectations which form part of their school knowledge, thus a teacher often understands a topic better after teaching it to students (Engelbrecht & Ankiewicz, 2016). For example, a teacher's subject knowledge is transformed by their own pedagogy in practice and by the resources which form part of their school knowledge. The active interaction of subject knowledge, school knowledge and pedagogical knowledge brings teacher professional knowledge into being (Banks, 2022; Banks & Barlex, 2014; Banks et al., 2004).

Banks et al. (2005) were critical of Shulman's work (1986) which is based on a teacher-centred pedagogy which focuses primarily on the pre-existing skills and knowledge that the teacher possesses, rather than on the process of learning. Gardner (1983) provides a perspective on professional knowledge which is rooted in a fundamental reconceptualization of knowledge and intelligence. Gardner's (1983) theory of multiple intelligences encourages a perspective on pedagogy that emphasises student understanding or the so-called learner perspective. Therefore, the focus shifts from teachers' knowledge to learners' understanding, from classroom technique to purpose (Banks et al., 2005).

Shulman (1987) identified seven types of teacher knowledge which Williams et al. (2016) described as domains or categories dealing with the complexity of the knowledge base that experienced teachers draw upon. MacNamara (1991) identified the following types of teacher knowledge: subject content knowledge; pedagogical knowledge; and school-subject knowledge. These types of knowledge were adapted and expanded by Banks (2008) as follows:

2.2. Subject knowledge

If the aim of teaching is to enhance children's understanding, then teachers themselves must have a flexible and sophisticated understanding of subject knowledge in order to achieve this purpose in the classroom. Therefore, teachers' subject knowledge influences the way in which they teach, and teachers who know more about the subject will be more interesting and adventurous in their methods and, consequently, more effective (Banks & Barlex, 2014). Furthermore, teachers with only a limited knowledge of a subject may avoid teaching difficult or complex aspects of it and teach in a manner which avoids learner participation and questioning which fails to draw upon learner's experience (Banks, 2008).

2.3. Pedagogical knowledge

In contrast to Shulman's (1986) pedagogical content knowledge, Gardner's (1983) work is rooted in a fundamental reconceptualization of knowledge and intelligence. Due to his theory of multiple intelligences pedagogy can now be viewed from a perspective on student understanding. There is now an emphasis on the *process* of pedagogy and therefore, a wider term of '*pedagogical knowledge'* considered a more appropriate term for use (Banks, 2008).

2.4. School knowledge

Banks (2008) added 'school knowledge' as another type of teacher knowledge which is not knowledge of the school context, but rather the transposition of subject knowledge. For example, by altering technology to make it accessible to the school students, a distinctive type of knowledge, 'school technology', is formulated. 'School technology' is a function of the schooling process and would exist even without a prescribed curriculum to guide its formulation and so is a general term applicable across different country contexts. Therefore, school knowledge is greatly informed by the local school ethos, common practices and authenticity of activities that students are required to undertake during their work in technology lessons (Banks, 2008). Technology student teachers must understand that the emphasis is on the design 'process' and 'portfolio' and their importance in the assessment process. The relationship between subject and school knowledge can be explained by Newton's second law as an example. From Newton's Principia the second law reads: *The rate of change of momentum of a body is proportional to the resultant force acting on the body and is in the direction of that force*. In symbolic form this becomes $\mathbf{F} = d\mathbf{p}/dt$. However, in school knowledge which deals with a single particle of constant mass, this formulation transposes (and is equivalent) to $\mathbf{F} = m\mathbf{a}$, because $\mathbf{F} = d\mathbf{p}/dt = d/dt\,(m\mathbf{v}) = m\,d\mathbf{v}/dt = m\mathbf{a}$.

2.5. Personal subject construct

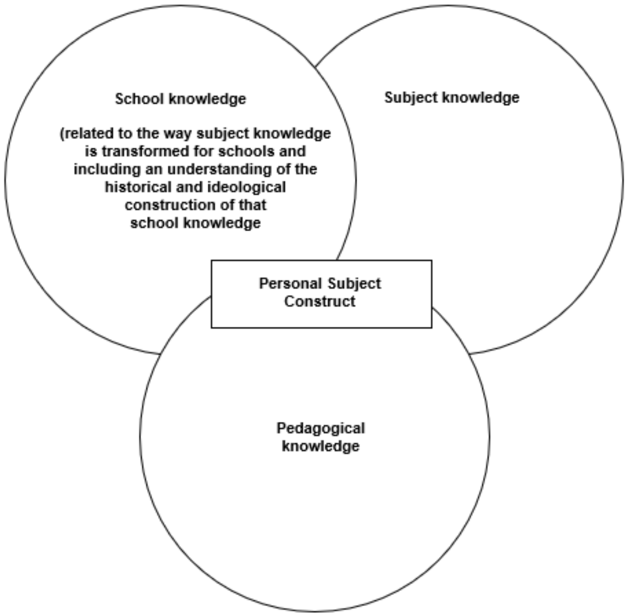
A teacher's professional knowledge is underpinned by his/her past experiences of learning technology, the personal view of what constitutes 'good' teaching and a belief in the purpose of technology as a school subject (Banks & Barlex, 2014). Therefore, the personal subject construct is a combination of school knowledge, subject knowledge and pedagogical knowledge which blend with other influences to provide a view of purpose, value content and methods of design and technology as a school subject (Banks, 2022). Furthermore, a student teacher must question his or her personal beliefs about their subject as they work out a rationale for their behaviour in the classroom. Banks (2008) believes that a teacher's 'personal subject construct' will have an important impact on the way in which they respond to a professional development activity.

2.6. Banks' revised model for teacher professional knowledge

Banks (2022) proposed Figure 1 as a revised version of previous models and provides a new starting point for conceptualising teacher professional knowledge. Shulman's category of subject content knowledge is retained but represented as subject knowledge. School knowledge, which includes Shulman's (1987) curriculum knowledge, is viewed as the transposition of subject knowledge and not merely a knowledge of the school context. Curriculum knowledge is

"…knowledge of relevant mandated curricula" (Banks, 2022:83), "…with particular grasp of the materials and programs that serve as 'tools of the trade' for the teachers" (Shulman, 1987:8). Pedagogical knowledge is more than the generic set of beliefs and practices that inform teaching and learning, it must be integrated into an understanding of the important relationship between subject knowledge and school knowledge. According to Banks (2022) a teacher's subject knowledge is transformed by their own pedagogy in practice and by the resources which form part of their school knowledge. The active interaction of subject knowledge, school knowledge and pedagogical knowledge leads to the personal subject construct of the teacher (Banks & Barlex, 2014). This construct includes past knowledge, experiences of learning, a personal view of what constitutes 'good' teaching and belief in the purposes of the subject.

Figure 1.
Teachers' professional knowledge (Banks, 2022:62)



The context that underpinned our study will be discussed briefly.

3. CONTEXT OF THE STUDY

Within the afore-mentioned collaborative learning environment and apprenticeship, the students who enrolled for this four-year programme either studied EGD in Year 12 at school and will be referred to as 'Group Y', or studied EGD postschool as part of an apprenticeship at university and will be referred to as 'Group Z'. The number of students and a breakdown in terms of cohorts and gender for both groups are given in Table 1. During their final year only one Group Y student and four Group Z students remained in the programme.

It is unusual to teach school knowledge in a university context. However, during the apprenticeship we simulated the school context, inter alia, by letting an expert, who was a schoolteacher, teach the Group Z students. We argue that the apprenticeship, which focused on the school subject EGD, exposed the student teachers to school knowledge, as the result of transposed subject knowledge, in a postschool-university context. However, it did not intend to develop the student teachers' competence to transpose subject knowledge into school knowledge, which they were supposed to acquire in the specialised methodology modules at the university and WIL in schools. During the specialised methodology/pedagogy modules, the students studied, inter alia, various teaching/pedagogical approaches, strategies, and methods which are required for the transposition of their subject knowledge to school knowledge, and which they then applied during WIL.

The students studied subject knowledge in their major (EGTE 1, 2 and 3) and generic pedagogy (Teaching Studies 1, 2, 3 and 4 and Teaching Methodology and Practicum 2). During their third year they also studied the transposition of subject knowledge into school knowledge, as well as pedagogical knowledge in the specialised methodology/pedagogy module (Teaching Methodology and Practicum for Senior Phase [Year 7–9] and Further Education and Training Phase [Year 10–12]), which focused on both technology and EGD. During their fourth year they practically applied the theoretical knowledge on the transposition of subject knowledge into school knowledge, as well as pedagogical knowledge in the module Teaching Methodology and Practicum for Further Education and Training Phase EGD. It also included ten weeks of WIL in approved schools – three consecutive weeks during the first semester and seven consecutive weeks during the second semester (Grobler & Ankiewicz, 2022b). Table 1 summarises the contextual information regarding the study.

Table 1.
Summary of the contextual information regarding the study.

Type of knowledge	Year, cohorts and module	Group Y	Group Z
School knowledge (Engineering graphics and design [EGD] as the result of transposed subject knowledge in Year 12)		Studied EGD in school context (up to Year 12)	Studied EGD in a postschool-university context
Subject knowledge (number of cohorts and students)	Year 1, EGTE 1, 2 cohorts [22 (12 male; 10 female)]	8 (6 male; 2 female)	14 (6 male; 8 female)
	Year 2, EGTE 2, 2 cohorts [21 (12 male; 9 female)]	8 (6 male; 2 female)	13 (6 male; 7 female)
	Year 3, EGTE 3, 1 cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)
Transposing subject knowledge into school knowledge (including pedagogical knowledge)	Year 3, TMP: SP & FET, I cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)

Pedagogical knowledge (including transposing subject knowledge into school knowledge)	Year 4, TMP: FET EGD, I cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)
	Year 4, WIL, 1 cohort [5 (2 male; 3 female)]	1 (0 male; 1 female)	4 (2 male; 2 female)

The discussion shifts now to a reinterpretation of the previous findings through the lens of Banks' TPK model by means of a qualitative meta-synthesis.

4. REINTERPRETING THE FINDINGS OF THIS LONGITUDINAL STUDY THROUGH THE LENS OF BANKS' TPK MODEL

4.1. Developing students' subject knowledge

For both cohorts in the first year, Group Y performed statistically significantly higher in EGTE 1 than Group Z students for both cohorts. By the end of the second year for Cohort 1, the performance of Group Y and Group Z was similar in EGTE 2. However, for Cohort 2 the performance of Group Y was statistically higher than those of Group Z in EGTE 2, which illustrates that findings can be very specific for a particular cohort (Grobler & Ankiewicz, 2022a). Furthermore, for Cohort 1 the performance of Group Y students (69%) and Group Z students (68%) in EGTE 3 was practically similar. Unfortunately, due to the small number of continuing students in the third and fourth year it was pointless to determine the statistical significance of any differences in performance between Group Y and Z. Thus, provided that ample support is available to meet students' needs and challenges they experience, Group Z students can succeed in developing their subject knowledge and skills at university level, which is a crucial part of the knowledge base for teaching (Rohaan et al., 2009).

Looking through the lens of Banks, this would indicate that Group Z students can successfully develop their subject knowledge, although it might imply a higher workload and additional time to catch up with Group Y students. Extra support should be provided during the first two years of their study to assist the Group Z students to scaffold the development of their subject knowledge. The comparisons between the two groups are based on *de facto* descriptions of their performance without drawing any causalities therefrom.

4.2. Transposing subject knowledge into school knowledge (including pedagogical knowledge)

According to Banks (2022) 'school knowledge' does not mean a knowledge of the school context but rather the transposition of the subject knowledge to make it accessible to learners, whereby a distinctive type of knowledge is formulated, for example 'school technology' (Banks & Barlex, 2014). The focus at university level should rather be on teaching students how to transpose subject knowledge into school knowledge by developing their competence to interpret the curriculum, draw up lesson plans, design assessment tasks, and learn about the compulsory formal assessment for promotion. When we assert that Group Z lacked school knowledge, we mean that they had not experienced school knowledge as the result of transposed subject knowledge by teachers.

However, both groups at the start of their fourth year lacked the competence to transpose subject knowledge to school knowledge for school students. The performance of both groups in their specialised methodologies was practically similar. During the third year Group Y achieved 60% and Group Z 63%, and during the fourth year Group Y achieved 75% and Group Z 77%. During the focus group interview after WIL a Group Z student recognised the difference between subject knowledge and school knowledge by saying that "EGD at school is different…−…the knowledge I have acquired at university is not classroom knowledge". Although the student teachers studied to interpret and teach the prescribed, national school curriculum (CAPS) the Group Z students missed out on the valuable past experiences of studying EGD at school and through Lortie's (1975) 'apprenticeship of observation' observing teachers transposing subject knowledge into school knowledge practically. During the individual interview after WIL the Group Y student acknowledged that the lecturers and the tutor helped her to improve her school knowledge and to prepare her well for WIL.

4.3. Developing students' pedagogical knowledge (including transposing subject knowledge into school knowledge)

To measure these students' PCK during their WIL experience in their final year of study, we relied on Content Representations (CoRes) and Pedagogical and Professional experience Repertoires (PaP-eRs) (Loughran et al., 2004). For lesson planning, as part of the CoRes, students applied their school knowledge by identifying 'big ideas' of the particular content or topics prescribed by the CAPS and set out by the annual teaching plan for the specific time period coinciding with their WIL. The big ideas for a specific topic highlight several concepts as being commonly viewed as important for students to learn in order to understand this topic (Loughran et al., 2004). By relying on both their subject and school knowledge, the students also implemented the set of eight pedagogical questions/prompts which interrogate each big idea (De Miranda, 2018; Loughran et al., 2004; Williams et al., 2016) across the various lesson phases.

The lesson presentation assessment rubric incorporates the various phases of the lesson such as the lesson design (written planning), introduction, presentation style, PCK, resources, classroom management and professionalism, assessment, conclusion and the student's reflection on the lesson plan and presentation. PaP-eRs were developed from students' detailed descriptions/reflections and as a result of discussions about situations/ideas/issues pertaining to the CoRes, as well as classroom observations (Loughran et al., 2004). The findings from the lesson presentation assessment during WIL indicated that the PCK of the Group Y student was slightly higher than the mean score of Group Z (82% compared to 78%). Therefore, according to Grobler and Ankiewicz (2021), the performance of students during these lesson presentations was regarded as competent as they demonstrated the required pedagogical knowledge (Banks et al., 2004; Shulman, 1986, 1987).

The students' PCK was also ascertained by using a classroom observation schedule consisting of 15 aspects based on CoRes and most of the aspects covered by the afore-mentioned rubric, including the observation of students' PaP-eRs. The assessment criteria for each aspect were: not achieved/not competent (1); developing/approaching competence (2); accomplished/competent (3); and exemplary/excellent (4). The scores for Group Z students varied between 1.6 and 2.8 with an average of 2.4 out of a maximum of 4.0 which is an indication of ranging between ‘approaching competence’ and ‘competent’ while the Group Y student scored 3.1 which is just beyond ‘competent’ (Grobler & Ankiewicz, 2021).

The focus-group interview after WIL regarding the experiences of Group Z students during their WIL period revealed that their experiences were good, although challenging. Some of the students felt that they were not well equipped to teach EGD (Grobler & Ankiewicz, 2021). One student mentioned that it was difficult to explain different concepts of EGD to the learners because they did not study the subject at school. The Group Z students felt that they lacked a proper foundation in the subject, and according to Gill (2019), this might compromise their ability to adapt subject matter for the purpose of teaching. However, it was found that the real challenge was when they had to do assessment and specifically the marking of assignments and tests (Grobler & Ankiewicz, 2021). It was recommended that students should gain more experience in the marking of assessment papers during the specialised pedagogy courses to develop their school knowledge before they do their WIL experience in their final year. Overall, the support from the mentor teachers was much appreciated to enhance their pedagogical knowledge.

4.4. Developing students’ personal subject construct

The combination of the students’ school knowledge, subject knowledge and pedagogical knowledge culminated in their personal subject construct. The findings revealed that both Group Y and Group Z students had similar experiences about the support and guidance by the mentor teachers during their WIL period (Grobler & Ankiewicz, 2021). All of them valued the support and guidance by the mentor teachers, and their perception of not being well equipped for the WIL period was mainly due to their lack of ability to handle assessments. The Group Y student reflected as follows:

> “Overall, the past weeks have been vastly beneficial to both my personal and professional growth. I genuinely feel that my experiences at the school, as well as the mentorship I have received, have helped me grow so much. While I feel saddened by the closure of the work-integrated learning experience for the year, I feel equally delighted to have emerged a better teacher from my experiences throughout the year.”

Banks and Barlex (2014) stated that a teacher’s professional knowledge is underpinned by his/her past experiences of learning technology which may indicate that the final year students might need special guidance to assist them in becoming familiar with the practice of handling assessment tasks. The students still need experience to develop their ‘personal subject construct’ which will serve as a crucial starting point for any future professional development activity. If the professional development activity unknowingly clashed with what the teacher thought technology was all about, then they would reject that development as ‘a complete waste of time’ (Banks, 2008). Table 2 provides a summary of the findings of the study.

Table 2.
Summary of the findings.

Type of knowledge	Year and module	Findings
Subject knowledge	Year 1, EGTE 1	For both Cohorts Group Y performed statistically significantly higher than Group Z.
	Year 2, EGTE 2	For Cohort 1 Group Y and Group Z performed similar. For Cohort 2 Group Y performed statistically significantly higher than Group Z.
	Year 3, EGTE 3	The performance of Group Y and Group Z was practically similar.
Transposing subject knowledge into school knowledge (including pedagogical knowledge)	Year 3, TMP: SP & FET	The performance of Group Y and Group Z was practically similar.
	Year 4, TMP: FET EGD	The performance of Group Y and Group Z was practically similar.
Pedagogical knowledge (including transposing subject knowledge into school knowledge)	Year 4, Aspects of WIL	
	Lesson presentation	The PCK of the Group Y student (82%) was slightly higher than the mean score of Group Z students (78%).
	PCK (CoRes and Pap-eRs)	The scores for Group Z students varied between 'approaching competence' and 'competent' while the Group Y student scored just beyond 'competent'.
	Experiences of WIL	Group Z had good experiences although challenging, and they lacked a proper foundation in the school subject. Some of them felt that they were not well equipped to teach EGD. One student mentioned that it was difficult to explain different concepts of EGD. Unfortunately, the Group Y student did not specifically comment on the WIL experience.
Personal subject construct		Both Groups Y and Z students valued the support and guidance by their mentor teachers during WIL, which added to their growth and development as a teacher.

5. CONCLUSION

The reinterpretation of the previous findings of this longitudinal study through the lens of Banks' TPK model (2022) has shed new light, especially on students' personal subject construct, which was largely overlooked in previous reports. It emphasises the importance of student reflections as part of their Pedagogical and Professional experience Repertoires (PaP-ers). It also confirmed that developing school subject knowledge without prior experience of school knowledge, as transposed subject knowledge at school, can successfully contribute to develop students' professional knowledge to the extent that they can be regarded as 'approaching competence' or 'competent'. The requirement for developing student teachers professionally via this parallel approach is that it happens within a social constructivist, co-operative learning environment (Johnson & Thomas, 1992; Reddy et al., 2005) with ample opportunities for cognitive and practical apprenticeship (Jakovljevic & Ankiewicz, 2016) in a community of practice (Banks, 2008; Banks et al., 2004). However, more focus should be placed on assessment when designing the curriculum of the programme for initial professional education of technology teachers. The students need more experience in the marking of assessment papers during the specialised pedagogy courses before they do their WIL experience. When the students are placed in schools for their WIL period, special care should be taken when the mentor teachers are assigned to the students so that they can assist these students to further develop their personal subject construct and therefore their professional knowledge (cf. Banks, 2022).

Acknowledgment

This paper was inspired by Frank Banks' PhD by Published Works thesis, which degree was awarded on 29 September 2022. The authors are grateful to him (in his position as Emeritus Professor of Teacher Education at The Open University, UK) for his valuable comments and advice as critical reader of the manuscript. We are also indebted to our former colleagues, Francois van As and Werner Engelbrecht, who were research partners in the programme, for assisting us in interpreting some of the data that we used for this paper.

6. REFERENCES

Ankiewicz, P. (2018). A Brief Overview of Technology Education in South Africa since 1994. Unpublished keynote address at the CETIS' Summer Seminar Rockelstadt, Sweden. 14 June 2018.

Ankiewicz, P. (2021). Technology education in South Africa since the new dispensation in 1994: An analysis of curriculum documents and a meta-synthesis of scholarly work. *International Journal of Technology and Design Education, 31*(5), 939–963. DOI 10.1007/s10798-020-09589-8.

Banks, F. (1996). Developing professional knowledge during initial design and technology teacher education. *Journal of Design and Technology Education, 1*(2), 175–178.

Banks, F. (2008). Learning in DEPTH: developing a graphical tool for professional thinking for technology teachers. *International Journal of Technology and Design Education*, *18*, 221–229. DOI 10.1007/s10798-008-9050-z.

Banks, F. (2022). Developing the Professional Knowledge of Teachers of Technology and STEM in Secondary Schools (PhD thesis). The Open University.

Banks, F., & Barlex, D. (2014). *Teaching STEM in the Secondary School: Helping Teachers meet the Challenges*. New York: Routledge.

Banks, F., Barlex, D., Jarvinen, E., O'Sullivan, G., Owen-Jackson, G., & Rutland, M. (2004). DEPTH – Developing professional thinking for technology teachers: An international study. *International Journal of Technology and Design Education*, *14*, 141–157.

Banks, F., Leach, J. & Moon, B. (2005). Extract from "New understandings of teacher' pedagogic knowledge". *Curriculum Journal, 16*(3), 331–340.

Department of Basic Education (DBE). (2011a). *Curriculum and Assessment Policy Statement (CAPS): Technology, Senior Phase Grades 7–9.* Pretoria: Department of Basic Education.

Department of Basic Education (DBE). (2011b). *Curriculum and Assessment Policy Statement (CAPS): Engineering Graphics and Design, Further Education and Training Phase, Grades 10–12.* Pretoria: Department of Basic Education.

De Miranda, M. (2018). Pedagogical content knowledge for technology education. In M.J. de Vries (ed.) *Handbook of Technology Education.* (pp. 685–689), Springer International Handbooks of Education. Switzerland: Springer.

Engelbrecht, W., & Ankiewicz, P. (2016). Criteria for continuing professional development of technology teachers' professional knowledge: a theoretical perspective. *International Journal of Technology and Design Education, 26*, 259–284. DOI 10.1007/s10798-015-9309-0.

Gardner, H. (1983). *Frames and Mind: The Theory of Multiple Intelligences.* New York: Basic Books.

Gill, D. (2019). The truth is in the boat: A case study of pedagogical content knowledge and technical skill development in pre-service technology education teachers. In S. Pulé, & M.J. de Vries (Eds.) *Developing a Knowledge Economy Through Technology and Engineering Education.* Proceedings of the PATT 37 Conference (pp. 167–176). Msida, Malta.

Grobler, R. (2018). Innovating an Initial Professional Education of Technology Teachers (IPETT) Programme. In N. Seery, J. Buckley, D. Canty, & J. Phelan (Eds.), *Research and Practice in Technology Education: Perspectives on Human Capacity and Development.* Proceedings of the PATT 36 Conference (pp. 156–166). Athlone, Ireland.

Grobler, R. (2019). Developing students' professional learning for an integrated curriculum by implementing an innovative Initial Professional Education of Technology Teachers (IPETT) programme. Yearbook of the 63rd International Council on Education for Teaching (ICET) World Assembly 2019 Conference (pp. 81–91). Johannesburg, South Africa. ISBN 978-1-4314-3004-8.

Grobler, R. & Ankiewicz, P. (2021). Experiences and competencies of final-year technology student teachers during their work-integrated learning: A longitudinal study. *Techne series: Research in Sloyd Education and Craft Science, 28*(2), 2021:400–408.

Grobler, R., & Ankiewicz, P. (2022a). The viability of diverting from a linear to a parallel approach to the development of PCK in technology teacher education. *International Journal of Technology and Design Education, 32*(2), 1001–1021. https://doi.org/10.1007/s10798-020-09644-4.

Grobler, R., & Ankiewicz, P. (2022b). Lessons learned from a parallel approach to the development of PCK in technology teacher education: A longitudinal study. In D. Gill, J. Tuff, T. Kennedy, S. Pendergast, & S Jamil (Eds) *PATT on the Edge: Technology, Innovation and Education.* Proceedings of the PATT39 Conference (pp. 291–302). Newfoundland and Labrador, Canada.

Jakovljevic, M., & Ankiewicz, P. (2016). Project-based pedagogy for the facilitation of webpage design. *International Journal of Technology and Design Education, 26*(2), 225–242. http://doi.org/10.1007/s10798-015-9312-5.

Johnson, S.D., & Thomas, R. (1992). Technology education and the cognitive revolution. *The Technology Teacher, 51*(4), 7–12.

Lortie, D. (1975). *Schoolteacher*. Chicago, IL: University of Chicago Press.

Loughran, J., Mulhall, P., Berry, A. (2004). In search of pedagogical content knowledge in Science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching, 41*(4), 370–391. DOI 10.1002/tea.2007.

MacNamara, D. (1991). Subject knowledge and its application: Problems and possibilities for teacher educators. *Journal of Education for Teaching. 17*(2), 113–128.

Reddy, V, Ankiewicz, P., & De Swardt, E, (2005). Learning theories: A conceptual framework for learning and instruction in technology education. *South African Journal of Higher Education*, *19*(3), 423–443.

Rohaan, E.J., Taconis, R., & Jochems, M.G. (2009). Measuring teachers' pedagogical content knowledge in primary technology education. *Research in Science and Technology Education, 27*(3), 327–338. DOI 10.1080/02635140903162652.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–22.

Williams, P.J., Lockley, J., & Mangan, J. (2016). Technology teacher's use of a CoRe to develop their PCK. In M.J. de Vries, A. Bekker-Hotland, & G. van Dijk (Eds) *Technology Education for the 21st Century Skills.* Proceedings of the PATT32 Conference (pp. 489–499). Utrecht, The Netherlands.