The Reciprocal Nature of Pedagogical and Technical Knowledge and Skill Development between Experts and Novices

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Abstract
This paper outlines the findings of a study focused on the impact an expert teacher's pedagogical and technical knowledge and skill may have on the pedagogical and technical development of pre-service technology education teachers. Specifically, this inquiry falls within the context of traditional wooden boat building in Newfoundland and Labrador, Canada. Understanding the relationship between an expert's knowledge and skill, and the development of a novice's knowledge and skill is vitally important for institutions charged with graduating technology education teachers. Exploring the impact of pre-service teachers' pedagogical and technical development was considered in relation to an expert teacher's pedagogical content knowledge, and the nuance between declarative and procedural knowledge within technological activity. Data were collected from semi-structured interviews, workshop session observations, and researcher/participant journal entries. The sample was purposeful as the participants were recruited from boat building workshops between 2017 and 2019 and the 2017-2018 technology education diploma program cohort from Memorial University. Thematic analysis was used to identify major themes within the data. A descriptive visual framework based on the data analysis was constructed to highlight the complexities of teaching and learning within the multifaceted setting of a technical activity. An analysis of the data indicates that fostering and maintaining reciprocal interpersonal relationships between experts, novices, and peers are critical for the development of pre-service teacher technical and pedagogical knowledge and skill.

Keywords
PCK, technical knowledge, skill development, pre-service education, technology education, expert, novice.

Research on technology education teachers' beliefs and practices has revealed that there is a difference in their understanding of the nature of content knowledge as compared to other subject area teachers (Doyle, Seery, and Gumaelius 2019). While teachers of science, social studies, and other well-established subjects may tend to focus on concepts and knowledge acquisition as the basis of their pedagogical practice, technology education teachers still tend to focus on technological activity with less emphasis on conceptual knowledge (Doyle et al. 2018; Jones, Buntting, and de Vries 2013; Williams and Lockley 2012). How teachers know and enact their practice has been described through various interpretations of pedagogical content knowledge (PCK) for the last three decades. While PCK was framed as the intersection of a teacher's subject matter knowledge, pedagogical knowledge, and context knowledge that informed their practice (Shulman 1986), this concept has matured. Moving away from a generalized elucidation of canonical teaching practice, the idea of situating PCK within specific teachers' experiences has emerged (Doyle et al. 2019). This evolution of thought on PCK may have a direct effect on technology pre-service education. As de Miranda (2017) has suggested, individual technology education teachers have their own unique domain specific knowledge and any hope of transmitting this knowledge to pre-service teachers is probably a near impossible task. Rather, as pre-service technology researchers and educators there is an opportunity to generate and evaluate useful pedagogical practices for the conceptual strains of technology education.

The idea of informing technology education teacher educators was the primary motivation for this study. Within the complex and situated nature of a technical activity, this paper will discuss the findings of a research study focusing on the question of whether the impact an expert teacher's pedagogical knowledge and skill and their technical knowledge and skill may have on the pedagogical and technical skill development of pre-service technology education teachers. Specifically, this question will be framed within the context of traditional small wooden boat building in Newfoundland and Labrador, Canada.

Context

Wooden boat building was an essential part of surviving in Newfoundland and Labrador, Canada for centuries. While this knowledge was once common throughout coastal communities, the advent of new synthetic materials, processing methods, and the demise of the inshore fishery in the latter half of the twentieth century, have all taken a toll on this traditional knowledge and skill. With no ties from the past to connect to the present, or plans to reach into the future, wooden boat building in Newfoundland and Labrador, Canada may be lost. Shils (1981) noted traditions that survive the test of time are those that evolve and adapt to changing conditions. As such, the Wooden Boat Museum of Newfoundland and Labrador has a mandate to protect, collect, and disseminate knowledge about the provinces' collective cultural heritage concerning the building and use of wooden boats throughout the province. Of primary importance to this study is the museum's technical wooden boat building knowledge. For the past four years (2017-2020), the Faculty of Education of Memorial University and the Wooden Boat Museum of Newfoundland and Labrador have jointly offered winter boatbuilding workshops and courses facilitated by a local master boat builder and teacher. These workshops and courses have provided a rich authentic context as pre-service technology education teacher candidates have participated in the workshops and the subsequent research study.

Theoretical Background

Expertise

What does it mean to be an expert? It has been suggested that superior human performance is predominantly acquired through experience (Ericsson and Smith 1991). While the acquisition of expertise was once thought to be the product of mastering general domain independent skills, this theory has given way to the idea that "expertness lies more in an elaborated semantic memory than in a general reasoning process" (Chi, Glaser, and Farr 1988:xxxv). Context matters in developing human performance and expertise and while general reasoning processes may not be as key as once thought, continued experience in a domain is still an important consideration (Chi et al. 1988). In particular, the idea of developing expertise through a combination of interactional socialization (the idea that you can develop an awareness and expertise through social immersion) and an individual's development of contributory tacit knowledge through practice of an esoteric skill, have been proposed as a more holistic sociological perspective on expertise (Collins and Evans 2018). In studying how an experienced teacher's expertise and practice influences pre-service teacher pedagogical and technical development it is important to understand some of the general fundamental differences between expert and novice thought and action.

While multiple theories and frameworks have been utilized to study the difference between expert and novice performance, similar findings persist. Using the structure, behaviour, and function framework Hmelo-Silver and Pfeffer (2004) found that experts had a deeper understanding of the behaviour and function of complex systems in comparison to novices' fixation on superficial structural features. Dixon and Johnson (2011) found similar patterns of simplistic reductionism in novices versus expert engineers using a conceptual framework of metaphors, analogies, and propositions while working through design problems. Engineering students relied on heuristics or "rules of thumb" to reduce the cognitive load while experts moved quickly to proposing solutions based on their divergent experience. The ability of experts to identify common conceptual structures across disparate surface features of design problems can take years of substantial experience to develop and is a key characteristic of what it means to be classified as an expert (Dixon and Johnson 2011). In terms of teaching expertise, Auerbach et al. (2018) found that expert teachers have the ability to better identify and respond to student thinking while creating opportunities for generative work compared to their novice counterparts. In addition, Auerbach et al. (2018) also noted that their sample of expert teachers varied a great deal in their interpretations of what constituted important elements of teacher knowledge. In essence, the experts highlighted the importance of context, which did not necessarily match with previously held viewpoints about set stages of expert development.

Dreyfus and Dreyfus' (1980; 2004) seminal work on expert development heavily emphasised five key stages: novice, competence, proficiency, expertise and mastery. While this model still has value in a general sense, critics have since pointed out that in real life, expertise lies much more on a continuum for each individual that can overlap multiple stages of the Dreyfus model. Dall'Alba and Sandberg (2006) theorized that the embodied understanding of the domain of practice is also an important consideration for understanding expert development –it is not just the transfer of professional knowledge, it is an intimate understanding of the professional practice as well. This idea about an embodied experience was reflected in the work of Collins and Evans (2018) earlier as they outlined fundamental underlying sociological aspects of developing expertise, both individually and in groups. Expertise is not something that can be achieved independently of the contextual and social boundaries of the domain in question. While these studies and theoretical works outline the importance of continued and sustained experience within an area of expertise, there should be an awareness that individual preferences and interests along with motivation and practice counters the idea that anyone can achieve expertise in any domain with just practice alone (Chi et al. 1988). In becoming an expert technology education teacher there should be an acknowledgment of the potential relationship between interest, motivation, practice, and experience within the technical and pedagogical realms.

Technical Knowledge and Skill

Subject matter knowledge or content knowledge in technology education can be conceptually problematic for novice teachers as it encompasses not only declarative knowledge, but also procedural knowledge. In its broadest sense, technology is a normative practice (Jones et al. 2013) with practitioners relying on both an understanding of declarative and procedural knowledge –what Ryle (1949) originally described as the difference between "knowing that" and "knowing how" (p. 28-29). While this may sound like an easy way to compartmentalize different types of knowledge, modern psychological theories point to a much more unified and dynamic view (Haye and Torres-Sahli 2017).

The relationship between cognitive (declarative) and tacit (procedural) technical knowledge was difficult to analyze before the professionalization of technological communities as this knowledge was generally diffused through master apprentice interactions (Laudan 1984). While much work has been done to capture procedural knowledge related to actively participating in particular technological activities, these attempts typically do not convey the nuance of knowing how to execute a skill. More importantly they do not capture how to execute a skill well –the act of doing technology is essentially a form of living knowledge that is critical for any given material tradition. As de Vries (2016) has mentioned "textbooks are no option for teaching and learning knowledge that cannot be adequately expressed in propositions" (p. 37). Therefore, the act of learning through doing is important for developing proficiency in understanding both knowledge and skill, as Eraut (2004) pointed out, tacit knowledge is not only the implicit acquisition of knowledge, but also the implicit processing of knowledge. Haye and Torres-Sahli (2017) theorize that we are unable to separate forms of knowledge, they do this by analyzing current theory in relation to William James' conceptualization of mind being a relationship between body, affective feeling, and temporal experience. In essence, knowledge is practical thinking. The mind is ever changing and the stream of consciousness it produces can be captured in a facsimile that has been represented as declarative knowledge. Therefore, Haye and Torres-Sahli (2017), stated that declarative knowledge is not independent and that a holistic understanding of knowledge can be viewed as "… a changing process rooted in bodily dynamics and history" (p. 53). This stream of thought or knowledge has to have a context –we are always thinking of something. For technology educationalists, artifacts are typically that something.

Is a technological artifact a type of knowledge, or is it merely the end state and a representative form of other types of knowledge? As discussed above, the distinction between a dualistic notion and separation of declarative and procedural knowledge is currently not as strong as it once was. While technology can be viewed through multiple lens, Mitcham's (1994) four modalities of knowledge, process, artifact, and volition are used extensively in technology education as a basic foundation (de Vries 2016). This connection between Mitcham's modalities highlight that an artifact is imbued with more than its physical characteristics, an idea that Baird (2004) took even further. Baird (2004) asserted that scientific instruments are material objective knowledge –that instruments (technical artifacts) hold their own knowledge independent of subjective justified true belief. This he holds true through the demonstration of various instruments that worked consistently and reliably but were based on wrong or disproven scientific theory. Therefore, instruments more than encapsulate knowledge, they are a form of knowledge in and of themselves. This idea has been found to be problematic from the perspective of traditional schools of thought on the nature of knowledge. As Kletzl (2014) pointed out, Baird's theses did not account for a distinction between scientific and engineering theory, in which the procedural knowledge needed to manufacture working artifacts can be independent of each other. Kletzl (2014) maintained a traditional view of knowledge as justified true belief and that while an instrument can encapsulate knowledge, it cannot be knowledge.

The multiple positions concerning the relationship between declarative, procedural, and artifact knowledge within the context of technological activity forms a continuum of thought and action, reaction and evaluation, and further action. Wrestling with these ideas is essential for pre-service technology education teachers as they begin to develop their own pedagogical and technical skill within this curricular area.

PCK and PCK&S

As mentioned earlier, PCK has now been theorized to be more than the collective teaching practice of a specific domain. The idea that there are multiple layers between canonical and individual PCK has allowed researchers to propose more nuanced methods for investigating PCK generally, and specifically within technology education (Doyle et al. 2018; Gess-Newsome 2015; de Miranda 2017). One such idea is pedagogical content knowledge & skills (PCK&S). While proposed for science education, the implications of this idea have value in technology education as well.

Gess-Newsome (2015) defined PCK as personal knowledge that teachers use to design and reflect on instruction. More specifically “PCK is context specific including the teaching of a particular topic in a particular way for a particular purpose to particular students” (Gess-Newsome 2015, p. 36). This idea can be related to the context and domain specificity of the development of expertise –that expertise, in this case teaching expertise, is context bound. Gess-Newsome (2015) also defined PCK&S as the “act of teaching” (p. 36) and this differentiates between what a teacher knows (“knowing that”) and what they are able to do (“knowing how”). PCK&S is the embodiment of PCK within context. As such, it is the dynamic enactment of a teacher’s ability to implement instruction, monitor student activity, and adjust their action based on in situ feedback from the context. While Gess-Newsome (2015) acknowledged that PCK&S is an elusive research subject to study due to its tacit nature, it is also one way to describe PCK in the context of an active classroom. These ideas were supported by a later study which confirmed the complex nature of trying to understand the relationship between teacher PCK and student achievement (Gess-Newsome et al. 2019). After working with 35 secondary teachers in a two year intervention focusing on developing stronger pedagogical and content knowledge in biology, Gess-Newsome et al. (2019) concluded that pedagogical knowledge was “… intertwined with the context of teaching specific students” (p. 961). It was also noted that while teachers in the study may have known how they wanted to teach, they may not have had the skill to achieve their goals. While this study illustrates the difficulty in capturing PCK in action for experienced teachers, novice teachers have similar experiences.

In evaluating preparedness to teach technology education Ramaligela (2020) used a 9E instructional model to analyze five pre-service teachers’ content and instructional knowledge during their practicums in South Africa. Categories of *elicit, elaborate, explain, explore,* and *enclose* were used to evaluate technology content knowledge (TCK), while *enlighten, engage, exchange,* and *evaluate* were used to evaluate technology instructional knowledge (TIK) during single classroom observations of the five teachers. While the length of individual observations could be problematic in determining a representative sample of the pre-service teachers’ instruction, nevertheless, Ramaligela (2020) reported that there was a wide variety in the pre-service teachers’ ability to meet the criteria set forth by the 9E instructional model. The findings of this study indicated that this particular group of pre-service teachers did not have the content or instructional knowledge to qualify as competent technology teachers. While not surprising on its own, considering that Gess-Newsome et al. (2019) has reported similar findings for experienced teachers, there is much to consider about how teachers at any stage of their careers can strengthen their pedagogical content knowledge and skill (PCK&S).

It is from the perspective of the overlap of expertise, technical knowledge and skill, and PCK and PCK&S that this case study is positioned to investigate the potential relationships between an expert teacher's technical knowledge and skill and PCK&S and pre-service teachers' understanding of the concepts conveyed, within the context of their own development.

Methodology

The case study framework of Merriam and Tisdell (2016) was used as the primary methodological guide for this inquiry. Their qualitative constructivist perspectives matched the purpose of the study and facilitated the emergence of the thick rich descriptions needed to comprehend the potential relationship between an expert teacher's pedagogical knowledge and skill, their technical knowledge and skill and the development of pre-service teachers' pedagogical and technical knowledge and skill. Merriam and Tisdell (2016) stated that "a case study is an in-depth description and analysis of a bounded system" (p. 37). Case and unit of analysis are analogous in case study research and is one of the fundamental features that delineate it from other qualitative methodologies (Baxter and Jack 2008; Merriam and Tisdell 2016; Yin 2014). The pedagogical and technical knowledge and skill of both the expert and pre-service teachers were the unit of analysis (the case) for this study as it was an intrinsically bound phenomena that was encapsulated within the wooden boat workshop program (Baxter and Jack 2008; Merriam and Tisdell 2016). The boundaries for the case included the winter wooden boat building workshops hosted by the Wooden Boat Museum and Faculty of Education, the workshop's instructor, and technology education pre-service teachers enrolled in the workshop as an extra-curricular opportunity. Since the study sought to understand a phenomenon that is deeply situated in context and was holistically and systematically bounded within an area that was not previously researched, it was situated as a qualitative exploratory case study. Within this methodological context, the following research question was proposed: How does an expert teacher's pedagogical and technical knowledge and skill influence the development of pre-service teachers' pedagogical and technical knowledge and skill?

Population Sampling and Data Collection

As there was only one instructor for the workshop, he was approached to volunteer for the study. The workshop instructor had more than 40 years of wooden boat building experience and approximately 15 years of instructional experience at the time of the study. He is considered an expert by his peers and the boat building community -locally, nationally, and internationally as demonstrated by a number of commissioned works for private and public organizations and his active contribution to the ongoing dialogue at conferences pertaining to wooden boats and their construction and heritage. As such, he was purposefully selected to participate in this study. Purposeful sampling was also used to establish the pre-service teacher participants. Students from the 2017-2018 Faculty of Education's technology education diploma cohort were approached to participate in the study. There were four potential positions available for pre-service volunteers out of a cohort of 20. Two students responded, one female and one male. Both pre-service teachers agreed to participate in the research study over the course of the twelve-week workshop. The female pre-service teacher had an English and religious studies background and the male a mathematics and computer science background and they represented a typical sample from the cohort.

Data were gathered over two separate workshops starting in the winter of 2017. During the 2017 workshop, a series of semi-structured interviews were conducted with the instructor along with researcher-as-participant observations, recorded in session journals. Three interviews in total were conducted with the instructor; two anchor interviews at the beginning and middle of the workshop based on my observations and journal entries and one post workshop interview. Sample instructor interview questions included: *1. What comes first for students –rules and piecemeal things (parts and order) or the bigger picture of design and pattern? 2. Are technical abilities more important that aptitude? 3. What role does knowledge play in teaching technical skills?* During the 2018 workshop sessions, the two pre-service technology education teachers engaged in prompted journal writing and post workshop semi-structured interviews as well. Sample pre-service technology education teachers interview questions included: *1. Were there any teaching techniques that helped you develop technical skills? 2. How did the relationship between you and the instructor influence your experience? 3. What was the role of peer interactions in your learning process?* Researcher observations and journals, instructor interviews, and pre-service teacher journals and interviews allowed for triangulation of data sources and methods. All interviews were digitally recorded and transcribed for analysis and pre-service journal entries were shared online with the researcher.

Data Analysis

Thematic analysis was utilized to analyze the interview, journal, and observation data. Specifically, the first and second cycle coding procedure of Miles et al. (2013) were used within the context of Braun and Clarke's (2006) six phase thematic analysis framework to uncover trends in the data. The interview transcripts were used as the primary source of data with the pre-service and researcher journals and observation field notes forming the context for triangulation of data sources and methods. As the data was read and re-read, preliminary codes and data chunks were created and identified in relation to the research question. A combination of summarizing words, in vivo, and process coding were used throughout this process. These codes were refined through a second cycle as meta-codes were created to facilitate the emergence of larger themes. These themes were then reviewed in relation to the whole data set to ensure each data chunk was located in the most appropriate category. The journals and observational field notes were then analyzed within the identified codes and were checked for new themes as well. Credibility (validity) of the study was increased through triangulation of data sources and methods, member checks, adequate engagement with the data, and data saturation (Baxter and Jack 2008; Bloomberg and Volpe 2012; Merriam and Tisdell 2016; Shenton 2004). Peer examinations were used to strengthen the dependability (reliability) of the study through the presentation of preliminary results for feedback (Baxter and Jack 2008; Bloomberg and Volpe 2012; Merriam and Tisdell 2016; Shenton 2004). The use of thick rich description and the selected sample also increased the transferability (external validity) of the findings (Merriam and Tisdell 2016). All participants agreed to participate through a process of informed consent with the acknowledgement that their identities would be difficult to conceal from the workshop participants and instructor due to the small size of the group. They had the opportunity to select their own pseudonyms, but if they did not, their names were still changed to protect their anonymity from a larger non-localized audience.

Findings and Discussion

Throughout the wooden boat workshops that were the technological context of this study the instructor put forward the idea that the "truth is in the boat". That "… the boat in itself, as it comes together, answers the questions". This simple but profound statement encapsulates the idea of what lies at the heart of technical and pedagogical development within the context of pre-service teacher education and wooden boat building. That the technologies we create are much more than the final output of a technical process, they are embedded with an aesthetic that is representative of the technique, values, and culture of a continued time and place and as we literally shape the technology, in this case a boat, the technology shapes us. From an analysis of the data the idea of pre-service teachers shaping and being shaped through their interactions within their contextual milieu has come to light. Three major themes emerged from the data in relation to an expert teacher's influence on pre-service teacher pedagogical and technical knowledge and skill: interactions and relationships, technical knowledge and practice (skill), and pedagogical reflection and observation. The analysis of the findings will be discussed within the context of these three major themes

Interactions and Relationships

Interactions and relationships were emphasised by all three participants in this study and can be related back to the idea of shared experiences within a professional context as outlined previously by Collins and Evans (2018) and Dall'Alba and Sandberg (2006). Three sub-themes emerged from the data in relation to this larger theme: Instructor to student interactions, student-to-student interactions, and the development of mutually respectful relationships. All three sub-themes were identified as having an influence on both the instructor and pre-service teachers' own development within the technical and pedagogical spheres.

Instructor to Student Interactions

The interactions between pre-service teachers and the workshop instructor were viewed as essential to both as they learned and were shaped by one another. This was illustrated when the instructor talked about the relationship between his assumed technical and procedural knowledge and the perspectives that his students brought to the experience. In essence, the instructor was reflecting on the fact that even after years of working in this area, new perspectives can bring new insights for both him and the students involved. This idea was captured by the instructor when he made the following comment:

> *And you learn a lot from them [students] because even though you think that a thing you do, like, you thickness plane a board; well within that thickness planning of a board there's tons of information, there's tons of detail that you can assume because you've done it so often… but the student that are asking the questions sometimes brings to your attention, sometimes that proper or more, ah, a better way…*

As the instructor pointed out above, the importance of these interactions and allowing students the freedom to question methods and procedures can refine his own pedagogical and technical practice while allowing students to build their own. This idea of mutually learning both technically and pedagogically was also reinforced from the pre-service teacher perspective. When describing the teaching and learning of a difficult technical aspect of the boat construction, the female pre-service teacher reflected on the teaching approach used by the instructor. In particular, she was impressed by his ability to recognize a weakness in his own explanations and examples within this context, and his ability to adapt in the moment to meet the needs of the students. She remarked:

> *Seeing this play out was insightful for me and my own teaching because I thought that [the instructor] handled the situation nicely, by saying that it will become more clear when we start doing it and he'll go over it some more when we see more of it rather than just hearing the explanation.*

This type of interactions are the building blocks of developing cohesion within learning groups and again illustrate the relationship between the conceptual and tacit nature of the knowledge being accessed and used by the participants. What could not be conveyed in its entirety propositionally became a whole through the technical action directly illustrating Haye and Torres-Sahli's (2017) ideas about the holistic and bodily non-dualistic nature of knowledge.

Student-to-Student Interactions

Interactions between the workshop participants, including the pre-service teachers, were also encouraged, and facilitated by the instructor. While the instructor viewed peer-to-peer interaction as an essential part of his pedagogical practice, he was also aware of group dynamics over time. As people formed groups naturally he always monitored (a key aspect of an expert teacher as outlined by Auerbach et al., (2018)) to make sure no one person was dominating the action as there is little benefit in developing a student's own technical skills if they only watch others, they must do as well. As it is the instructor's belief that "… action will reinforce the lesson" he made an effort to move participants from group to group "…. to make sure that they have to do the action because the action is going to complement the knowledge..." This idea is a concrete example of the instructor's self-awareness of the interconnection between conceptual and procedural knowledge that has been identified as key in developing expertise in a domain (Haye and Torres-Sahli 2017; de Vries 2016). The female pre-service teacher also reflected on the role of group dynamics and the importance of learning from peers. This is vividly illustrated from an excerpt from one of her journal entries below:

> *Tonight, Chuck took me up to the boat and explained to me further the concept of the bevel on the boat. While the instructor explained this to me on paper and with the aid of the guide, Chuck brought me to the boat and showed me where the bevel applies and how it changes along the length of the boat, with it being the most straight towards the*

> *mid-ship bend. Seeing it this way made it much more clear to me, as I am usually a visual learner. Chuck was also very knowledgeable about this and had a very clear interest in this part, and it was great to share in his infectious enthusiasm as well as to be the member he decided to share this with. I understood the concept much more clearly though his explanation.*

This clearly demonstrates the distributed aspects of participating and learning technical skills within a group setting that would be comparable to other technology education learning environments. It also highlights the importance of meaningful relationships between peers throughout the entire process and again reinforces the socialization aspect of becoming an expert (Collins and Evans 2018).

Mutually Respectful Relationships

From a pre-service teacher perspective, the idea of trust and relationships between student and instructor and peer-to-peer was evident. Both pre-service teachers felt that without building trusting relationships learning can be hindered. The idea of reciprocating the instructional role with other participants was also highlighted as the female pre-service teacher mentioned feeling empowered when she was able to successfully teach another older participant a lamination technique. This feeling of empowerment is illustrative of the instructor’s view about the importance of students learning from each other. This idea of relationship building was also very important between student and instructor. As the female pre-service teacher mentioned:

> *My favourite moments from him [instructor] was when I’d be stood up waiting for my part to come up or waiting for our board to come out of the planer, or whatever and he’d be there, “I’ve got to tell you ..., let me tell you about this story…” And just building that relationship made me trust him and trust what he was telling me even more when it came to him passing on an instruction.*

These seemingly simple and mundane interactions and experiences provided a platform for the instructor to gain insight into multiple aspects of his students in relation to such things as their technical background and interests. This information can be invaluable for pedagogy in practice or what Gess-Newsome, (2015) called the “act of teaching” (p. 36). As the male pre-service teacher commented, the instructor understanding the dynamics of a classroom “… comes back to knowing your students. Knowing how well they’re doing, what their skill level is, what their comfort level is." This data complements the findings of Auerbach et al., (2018) that more than technical and pedagogical skills are at work in influencing pre-service teachers’ development. It would appear that the interpersonal has a significant role as well.

The analysis of the data within this theme clearly illustrates the importance placed on instructor to student and student-to-student interactions within the larger social context of developing and maintaining positive supportive relationships. The data points to the importance of a strong connection to both the instructor and the group in supporting the pedagogical and technical skill development of pre-service teachers. Their authentic and meaningful involvement within the sociocultural context cannot be understated in relation to the next theme: technical knowledge and practice (skill).

Technical Knowledge and Practice (Skill)

The importance of having or gaining a solid understanding and experience with the techniques of the contextual technical domain was a prominent theme that emerged from the data. As Shulman (1986) stated, pedagogy without content knowledge is useless, therefore understanding the relationship between the two is important because of the nuances between declarative and procedural knowledge that make up much of the content of technical domains. It is difficult to separate the technical from the pedagogical as the data would suggest an interplay exists between the two. Two sub-themes emerged in relation to the larger theme of technical knowledge: Instructor's technical perceptions and students' technical perceptions. Each of these themes lends insight into how an expert teacher's technical knowledge and skill may influence the development of pre-service teachers' technical knowledge and skill.

Instructor's Technical Perceptions

From the instructor's perspective, his educational and practical experience over the last 40 years has had a significant influence on his understanding of the declarative and procedural knowledge associated with wooden boat building. Combinations of informal and formal education within the context of personal necessity have shaped the instructor's technical perspective. The instructor recognizes explicitly the importance of multiple forms of knowledge and the relationship between conceptual and tacit. While he stressed the importance of declarative knowledge in understanding the bigger picture or concepts involved, he also noted "… you have to do, you have to use your hands, you have to use your mind, you have to, you know, but in particular you have to build". This is an explicit example of the tension between "knowing that" and "knowing how" and can be viewed as a point of transference of the instructor's conceptual knowledge into what Baird (2004) would call objective material knowledge. This tension is illustrated below as the instructor related the difficulty of expressing in words how to cut the angle of bevel on each frame when getting ready to plank a boat.

> *And to describe a curve in words, the metaphor; you can find metaphors for it, and I do seek them out, but the metaphor itself for it is not – it's only so small compared with the bending of a batten, and the connecting of the individual piece that we're working on. As you pointed out, the bevel, that batten takes that bevel from that frame at that point. Say it's frame number 3 the mid-frame in the boat, or one ahead or one aft of that, and explaining it now that bevel with the batten the visual of that tells you exactly the angle to cut, whereas the words prior to putting that batten on are weak.*

The instructor's self-awareness of these knowledge representation difficulties lies at the heart of the struggle of pinning down content knowledge within technology education. This self-awareness has developed over many years as the instructor described a familiarity that allows him to make design and technical decisions fluidly where he generally focuses on smaller tweaks on a larger whole. This idea relates to Dixon and Johnson's (2011) idea that experts can make connections to common conceptual structures across disparate surface features while working in problem spaces, whereas novices cannot.

Students' Technical Perceptions

Pre-service technology education teachers reported developing greater confidence and ability with both general and specific technological knowledge throughout the workshop process. The male pre-service teacher remarked that his comfort level with various techniques and tools had increased through a combination of one-on-one and group demonstrations, and individual practice. Both pre-service teachers stressed the importance of understanding the sequence of a technical process before assimilating that process into the bigger whole. As the male pre-service teacher expressed:

> *Ok this is the skill that I'm learning, where do I start, what do I need, what's step one, what's step two, what's step three, and then I worry about how it fits in. Like, I worry about the hows and the whys and I worry about that later.*

Throughout the course of the workshop both pre-service teachers relied on the experience of their instructor as a model for building their own technical expertise moving forward. The pre-service teachers also related how they were constantly thinking about how the general and specific technical knowledge and skills they were developing could be applied to their own classroom situations in the future. While this modeling of instruction was specific to the boat building context, it also sheds light on the importance of this approach in other technology education related curricular areas. As Gess-Newsome et al. (2019) and Ramaligela (2020) have both reported mixed levels of content and instructional knowledge in pre-service and in-service teachers this type of self reflection may be one key to decreasing this deficit. While the procedural knowledge was an important aspect of student technical development, in this case as mentioned above, the wider picture of the task gave the procedural knowledge a solid context. The female pre-service teacher articulated the importance of this interconnection when she said:

> *I like steps. Like, if I can break something down, but I can't do a step if I don't see the purpose of the whole thing. So, I want a big picture, I want to see that we're making a boat, but OK now let's break it down and we're going to do the keel first and this is how we do it. So, here's five steps to making the keel. Let's go and get it together, and then I'll take you back and we'll relate it to the big picture for the next step.*

As illustrated above, the pre-service teachers had a good mental representation of the final artifact in question, something that is not always the case when students are engaged in open ended design problems (Dixon and Johnson 2011). Problem solving in this case was confined to a contextually and culturally well-known artifact. Everyone generally had a rough approximation of what a small wooden boat looks like which may have helped the pre-service teachers deconstruct the task.

The data would suggestion that students found procedural technical aspects within the context of their instructor modeling techniques as useful for developing their own technical knowledge and skill. While the students did not directly discuss the explicit nature of technical knowledge, their ability to conceptualize the whole in relation to its parts may indicate the starting point for this inquiry. An inquiry that they may bring to their own pedagogical practice.

Pedagogical Reflection and Observation

Understanding student expectations and prior skill and experience was emphasised by all three participants in this study as a key theme related to their current and developing pedagogical knowledge and skill. Two sub-themes emerged from the data in relation to this larger theme: Relationship building, and the importance of modeling and reflecting on instructional practices. The data analysis has highlighted that these sub-themes had an influence on both the instructor's and pre-service teachers' pedagogical development.

Relationship Building

The instructor emphasised the role of understanding and building relationships with each set of students he encounters. He conveyed the importance of getting to know his students throughout the teaching process as a means of better meeting their needs. He generally broke this down into an informal process of conversation and observation driven inquiry. This informal, but systematic inquiry allowed him to ascertain students' self-perceived knowledge and skills in relation to the workshop content with his own observational evaluation of their actual level of competency, which he may judge below, above or accurate. Student driven questions forms one layer of this process that the instructor described as a valuable pedagogical strategy:

> *So, the more questions that individual is asking, it's sort of like a fog horn, you know, it's giving you directions, right. And so, for me, when I see some of the questions – hear some of the questions, I realize that some of the things have gone back a step or two prior to that question they're asking now was actually obvious the previous class. So, that gives me an alert to pay attention to that person and to bring them back and bring them to the boat if it's there, where it's done, and I could explain it.*

As illustrated above and corroborated from the field notes and my journal entries, these types of questions form organically throughout the process of the workshop and are not from the pre-conceived assumptions of the instructor and could be considered the personification of Gess-Newsome's (2015) PCK&S. The male pre-service teacher drew parallels between this questioning technique as a method of understanding everyone's differing ability levels and the importance of recognizing this in a K-12 technology education context. This pedagogical lesson on the importance of applying different teaching strategies for different students was captured in an excerpt from his journal entry below:

> *For this project in particular, the huge divide between the various skills levels of the participants requires extra care taken to ensure that more competent students are allowed to work independently sooner, while less comfortable students may require more hands-on instructional time. This principle carries handily into the average Tech Ed classroom, where students will be coming from a variety of technical backgrounds and levels of interest in course content, and the instructor must balance the varied needs of all of their pupils.*

Gaining this type of insight into the standing of individual students, especially early in a course was reiterated by the female pre-service teacher. She emphasised building trusting relationships and the idea of having empathy for her future students when she stated:

> *We all stood around and like the 20 of us that started, we all had a bunch of different backgrounds, and experiences, and skill levels with all the stuff, but we were all nervous as hens at first because of everybody, maybe they're better, maybe they thinks that we're stund [sic] with this tool or whatever. Um, so, just knowing that, like, as a teacher all of my students are going to feel that way too…*

She went on to state that it was important for her to understand that her future students may have similar feelings within technology education courses and that she wished they could come to her class with a more level technological literacy to ease these types of feelings. Both pre-service teachers exhibit similar traits as Ramaligela (2020) found within a sample of other students, but they also exhibit a great deal of reflexivity about their own ability as technology teachers at this particular moment in time. This self-reflection within the context of their own experience may be a powerful indication of the influence working with an expert teacher may have on pre-service teacher pedagogical knowledge and skill development and is reminiscent to the master-apprentice relationship described by Laudan (1984).

Modeling and Instructional Reflection

The master-apprentice idea resurfaced in the second sub-theme as it focused on the observation of expert practice in relation to developing pedagogical knowledge and skill. While the instructor reflected on multiple teaching and learning experiences over his career, it was interesting to note the dichotomy in his own pedagogical practice and his first technical learning in this domain. He mentioned that many builders were not teachers in the traditional sense as illustrated below:

> *A lot of the builders, in particular the traditional builders of Newfoundland and Labrador, it was all look and see. You know, you had to – they were not talkative, you know. Some of them were, but I saw a lot of boat builders whose explanation was – they had no*

> *words for it, they showed you. And sometimes they wouldn't even show you, you had to look at them; you had to really just follow them around to find out what was on the go with certain fits and that.*

While this was one experience in a long list described by the instructor in his own path, the male pre-service teacher summed up the downside of such pedagogical practice when he stated that a "… teacher who knows everything is all well and good, but that doesn't help me if I can't figure it out". He also added that it was opportunities to observe different approaches throughout the workshop and other instances of instruction throughout his technology education diploma that helped him build a context for his own pedagogical practice. He noted that in addition to participating in and observing the pedagogical practice of the current instructor he had the opportunity to:

> *… add to getting to see how you [author] run a shop, getting to see how [university instructor] runs a shop, it was just another experience to sort of add to my list of, well this is – these are ways you can do it, so what works best for me.*

The opportunity to observe and reflect on the instructor's approach to teaching gave both pre-service teachers a chance to compare and contrast their own pedagogical understanding with that of an expert teacher. Again, this seems to point to the importance of a holistic approach to pre-service technology education teacher programming where a strong reliance on modeling and mentorship is key. Pre-service teachers need to understand that they are very much novices and that they have just begun a journey of technical and pedagogical development that will hopefully last their entire careers. With that being said, how do we best represent these ideas to pre-service students and educators?

Sociocultural Contextual Framework

Based on a review of the literature and the analysis of the data a descriptive framework has been developed to visually represent the relationship between the types of knowledge and skill and the importance of the sociocultural context in relation to pre-service teachers developing their own pedagogical and technical knowledge and skill. It is hoped that this framework may be useful in a meta-cognitive discussion of the roles and responsibilities of pre-service technology teachers and the experts charged with their education. Figure 1 illustrates this framework and its guiding concepts. Based on the complexity of trying to separate knowledge from action, the pedagogical and the content knowledge (technical knowledge) have been placed as the foundation of the framework as understanding these ideas and the relationship between them are viewed as paramount. They have also been joined to signify their interconnected relationship. Without a solid understanding of these concepts, it is very difficult for technology teachers to articulate their actions outside of a superficial descriptive stance. It is also important to note that the entire framework is also anchored to the actual technological activity that is being taught as illustrated by the inner square that connects all the elements of the diagram, again reiterating the idea that there can be no knowledge without activity.

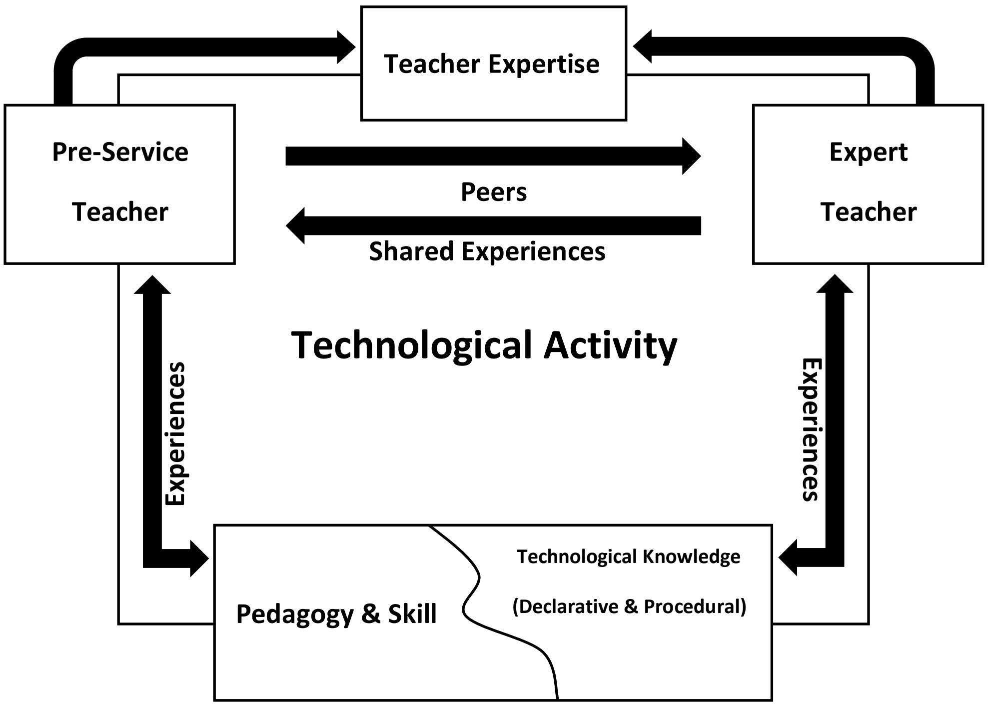

Figure 1: Sociocultural contextual framework of pre-service pedagogical and technical skill development

As a teacher (pre-service or expert) continues to gain experience within the pedagogical and technical domains, it is theorized that their expertise also increases as indicated by the bi-directional arrows connecting teachers with pedagogical and technical experiences. As they continue to gain experience in the pedagogical and technical, their expertise continues to grow. This is the case for both pre-service (novice) and established (expert) teachers. Although this is the case for both the novice and expert, the framework highlights that this development is not isolated to an individual. As the literature review and the data analysis revealed, there is a continual interexchange of shared experiences for both pre-service and expert teachers as they work through a technical activity together. This sociocultural context is also compounded by the shared experiences of classmates and other expert teachers through the course of the technological activity. What the framework does not account for is the quality of pedagogical and technical experience or the rate of expertise gained. The assumption for this study was that the quality of the pedagogical and technical experiences would be high, and as such, this is a significant limitation as this can not be guaranteed in general technology education classroom settings. This case study was not situated in a typical context; therefore, its transferability may be limited. Another limitation was related to the degree to which pre-service and expert teachers continued to gain expertise –was the gain linear or non-linear in relation to their experiences? These types of questions cannot be readily answered by this research design but could be addressed in further studies.

Conclusion

The data analysis and resulting framework has helped conceptualize and answer the main research question of the study buy succinctly highlighting the relationship between an expert teacher's pedagogical and technical knowledge and skill and the developmental pathway of pre-service teachers' pedagogical and technical knowledge and skill. Moreover, from the context of the wooden boat workshop not only is the expert teacher implementing a lesson on a technical skill, he is also implicitly delivering a pedagogical lesson as well. Therefore, from this perspective teaching and learning are a reciprocal activity in which the transfer of knowledge and skill is not a unidirectional action, but rather can be viewed as a partnership where all engaged parties benefit by increasing their expertise. While the framework is a very simple generalization within one local context of the complexity of how pre-service teachers develop their pedagogical and technical knowledge and skill, it nonetheless can be helpful as a planning and reflective tool for those charged with pre-service education and the pre-service teachers themselves. The idea that learning is a very social and interactive phenomenon is not something new to the educational research community, but those charged with undergraduate education must remember that their students will typically have a very basic and naïve formulation of the nature of teaching and learning. Therefore, it is very important to present research such as this, and more importantly, to make sure pre-service technology teacher education is configured to explicitly model and openly discuss these factors. While this study did not seek to quantify the types of activities or the amount of time required to develop expertise, it may be advisable to set up learning environments that acknowledge the reciprocal relationship between expert and novice and make explicit reference to the difficulty of understanding technical knowledge within the context of pedagogical practice. This may be one key to developing greater instructional and content knowledge for emerging technology education teachers.

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