Reconceptualising PCK research in D&T education: proposing a methodological framework to investigate enacted practice

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Reconceptualising PCK research in D&T education: proposing a methodological framework to investigate enacted practice

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Abstract Since first conceived, the concept of pedagogical content knowledge (PCK) has attracted much attention. Despite being lauded by educationalists as the unique knowledge base of teachers, research on the concept over the past 30 years has yet to result in a universally accepted definition being presented. Much of the contentions surrounding the lack of an agreed upon conception appear to have stemmed from difficulties in understanding the relationship between PCK, other areas of teacher knowledge, teacher beliefs, and enacted practice. This paper considers the application of PCK frameworks to design and technology (D&T) education, through an analysis of the nature of the discipline from an ontological and epistemological perspective and contemporary perspectives on the construct of PCK. It is theorised that the volition afforded to teachers in D&T through weakly framed subject boundaries negates the effective application of PCK frameworks, as teachers' beliefs have a greater impact on enacted practices. In an attempt to better understanding enacted practice in D&T education, the paper proposes a methodological framework centred on the interactions between teachers' beliefs and knowledge in the discipline, through synthesising the concept of amplifiers and filters of practice with the nature of D&T education. The proposed framework outlines the need to recognise individual teachers' conception of capability as a critical influence on enacted practice.

Keywords Enacted practice · Design and technology education · Amplifiers and filters of practice · Pedagogical content knowledge · Conception of capability

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Introduction

Since its inception in the mid-1980's (Shulman 1986, 1987) the concept of pedagogical content knowledge (PCK) has attracted much attention. Despite being lauded as the unique knowledge base of teachers (Borowski et al. 2012), PCK has proven difficult to define and several conceptions have been put forward over the past 30 years (*c.f.* Cochran et al. 1993; Gess-Newsome 2015; Grossman 1990; Loughran et al. 2008; Magnusson et al. 1999; Park and Chen 2012; Park and Oliver 2008). Many of the difficulties in defining the concept appear to have stemmed from the complex relationships that PCK shares with teachers' beliefs, and other areas of teacher knowledge, such as general pedagogical knowledge or subject-matter knowledge. In the absence of a universally accepted conception, researchers have begun to question the nature of PCK (Gess-Newsome 1999) and have subsequently outlined the need to shift from descriptive conceptions and utilise more explanative models of the concept (Abell 2008). Following such calls to action there have been attempts in both science (Gess-Newsome et al. 2017) and mathematics (Baumert et al. 2010) education to explore the relationship between PCK and practice. However, the results of such studies have been far from conclusive, as researchers have noted that the relationship between PCK and enacted practice is inherently complex as their interplay involves both knowledge-on-action and knowledge-in-action, and teacher knowledge is in part tacit and therefore difficult to elicit (Barendsen and Henze 2017).

The allure of a concept with the potential to depict expertise in teaching (Abell 2008) and aid in understanding enacted practices (Park and Oliver 2008) has resulted in many calls for PCK research in design and technology (D&T) education (de Vries 2003, 2015; Engelbrecht and Ankiewicz 2016; Jones et al. 2013; Mioduser 2015; Ritz and Martin 2012). Despite theoretical approaches to conceptualising a model for enactment (Jones and Moreland 2003, 2004), and applied approaches to measuring PCK through multiple choice questionnaires (Rohaan et al. 2009, 2012), the relationship between PCK and practice in the discipline is not necessarily understood. Williams, Lockley, and Mangan (2016) suggested that the degree of international diversity regarding the content of D&T may have served as an impediment to the development of research in the area, as the implicit nature of knowledge (Kimbell 2011; Williams 2009) is theorised to have a significant impact on enacted practice. Cognisant of the difficulties in understanding the relationship between PCK, teacher beliefs, and practice in science and mathematics education, and the complex nature of knowledge in D&T education, it is theorised that the application of current frameworks to D&T may be premature as the potential for variability in application is increased. In an attempt to better understand enacted practice in D&T education this article considers contemporary research on PCK and teacher beliefs, subsequently framing a methodological approach to explore their relationship with and influences on enacted practice in D&T. First however, it is important to explore D&T education from an ontological perspective and discuss how contemporary understandings of the nature of D&T education distinguish it from other disciplines.

The nature of D&T education

With rare exception D&T education internationally has evolved from a vocational background, which traditionally sought to meet culturally specific economic needs. Over the past 30 years, the philosophy of D&T in various cultures has begun to somewhat align, and with a shift towards a shared agenda for D&T internationally came new understandings of what is of importance to student learning. Whereas vocational subjects were primarily concerned with the transmission of specific content knowledge and development of specific skills (Banks 2000; Owen-Jackson 2015), D&T education is broadly characterised by its potential to develop transferrable knowledge, skills, and attitudes (Dow 2014). In spite of the clear distinctions between the nature of vocational and D&T education, it is debated whether or not practices in D&T have shifted in alignment with international discourse and policy changes (Banks and Barlex 1999; Dakers 2005a; Doyle et al. 2017; Mittell and Penny 1997). Much of the contentions in understanding the evolution of practice from vocational to D&T education appear to have stemmed from the difficulties in explicating goals for D&T, as researchers in the discipline appear to broadly converge on either the concept of technological capability (Black and Harrison 1985; Gibson 2008; Kelly et al. 1987; Kimbell 2011) or technological literacy (Dakers 2014a, b; Gagel 2004; Ingerman and Collier-Reed 2011; Petrina 2000, 2007; Williams 2009). In discussing the differences between technological capability and technological literacy, Kimbell and Stables describe the contention between the terms as the "transatlantic dissonance" (2007, p. 22) in D&T education. Kimbell and Stables (2007) state that the emphasis placed on capability in England and Wales was predicated on the learner's ability to operate as a design and technologist, situating the learner at the centre of design and technological activity. This aligns with initial conceptions of technological capability, where the focus was on one's capacity to combine designing and making skills, ensuring cognisance is taken of the processes and content required (Black and Harrison 1985). Gibson (2008) highlighted that the interactions between problem-solving, value-laden decision making and relevant skills, all housed within a conceptual knowledge base are fundamental to the espousal of technological capability. Apparent from such conceptions is that the development of technological capability necessitates engagement with task-centred activities which facilitate interactions between knowledge, skills and values (Kimbell 2011). On the other hand, the term 'technological literacy' is primarily used in the United States. Kimbell and Stables (2007) noted that the primary emphasis within the development of technological literacy is the learner's understanding and use of technology. Although this statement may have been true of initial conceptions of technological literacy, more recently the discourse around technological literacy appears to have surpassed this. For example, Williams (2017) discussed the concept of technological literacy and suggests that it is arguably the most significant goal of D&T education programmes, noting that it is generally constituted of an ability/use dimension, a knowledge and understanding dimension and an awareness or appreciation of the relationships between technology, society, and the environment. Williams views these as the foundational categories of technological literacy and acknowledges that curricula then "elaborate on the specific abilities or outcomes related to these dimensions that are to be achieved in order to reach a school-based level of technological literacy" (2017, p. 139). Critical here is the notion of a school-based level of technological literacy. Dakers compellingly argues the non-definable, non-certifiable, and non-examinable nature of technological literacy, stating that "one can only ever be in a state of becoming technologically literate" (2014b, p. 20), suggesting the need to identify levels of attainment for particular grade levels. Efforts to this end have been attempted (ITEA 2000, 2002, 2007), however as the subtitle of these publications suggests, they are ultimately concerned with depicting the "content for the study of technology". Ingerman and Collier-Reed (2011) subsequently noted the importance of understanding the *function* of technological literacy, which is less articulated in the literature. However, a more pertinent issue is the negative implications of defining the *content* and *functions* of technological literacy. In spite of the apparent logic of atomising specific elements of technological capability or technological literacy to specific attainment targets, the inherent complexity which emerges from such an approach is the need to define the specific content, knowledge base, skills, outcomes and outputs for enactment. In doing so, a unique characteristic of D&T education may be lost, as it is arguable that the level of diversity afforded in D&T is the defining characteristic of design and technological activity, as activity with no purpose beyond teaching a skill or internalising a piece of knowledge would more appropriately be called craft, science or history, dependant on the knowledge or skill involved (Kimbell 1994). Kimbell and Stables describe this phenomenon as "the importance of uncertainty" (2007, p. 24), and cite Hicks (1983) in articulating the intricacies of learning in D&T;

> Teaching facts is one thing; teaching pupils in such a way that they can apply facts is another, but providing learning opportunities which encourage pupils to use information naturally when handling uncertainty, in a manner which results in capability, is a challenge of a different kind.
>
> (Hicks 1983, p. 1)

In light of the difficulties in articulating the specific content knowledge that is of importance to student learning in D&T education, there have been efforts to depict the overarching concepts in the discipline through the development of an ontology of goals for K-12 engineering technology education. The approach taken by Rossouw, Hacker, and de Vries (2011) to explore and identify elements of the concept-context relationship in engineering technology education is particularly useful in bridging the gap between abstract concepts in the discipline and the applicability to different contexts. A modified Delphi approach with participants from the international research community identified five main concepts for use in curriculum development; (1) designing ('design as a verb'), (2) systems, (3) modelling, (4) resources, and (5) values. It is important to note that the concepts identified are context independent (although suggestions are offered in the paper), suggesting the far reaching applicability of such findings.

The difficulties in articulating explicit goals for D&T and describing activity in the discipline as operating in a place of "half-knowing" (Kimbell 2011, p. 9) relates to philosophical explanations of technological knowledge. As in alignment with the tacit nature of the goals of D&T, the classical philosophical notion of knowledge as *justified true belief* does not necessarily apply to technological knowledge (de Vries 2005, 2016). Norström (2014) suggests that the main reason for this stems from technological knowledge's inherent action orientation, as the discipline is less concerned with whether knowledge is true or not, as it is instead focused on whether the knowledge is successful in guiding actions towards certain goals. This goal-oriented agenda to the application of appropriate knowledge in part highlights the difficulties in the development of an epistemology of D&T education, as the variability in 'relevant' knowledge is dependent on specific goals which negate the construction of commonly agreed networks, or schema of knowledge. Further to this, there is no defined schema of technological knowledge as design and technological activity requires the learner to borrow knowledge from other disciplines (de Vries 2016, p. 36). In alignment with this, and in an attempt to describe the nature of the discipline from a content perspective, McGarr and Lynch (2017) identified the weakly classified nature of knowledge in D&T, situating it in the weakly classified and weakly framed quadrant of Bernstein's (1975) curriculum code framework. Irrespective of the content knowledge or organisation of knowledge in a discipline, aligning enacted practices and thus student learning with the educational objectives prescribed in curricula must be of critical importance. If D&T is characterised by the nature of activity recognised as evidencing technological capability or technological literacy, and if the discipline is further characterised by its boundary-crossing nature relative to content knowledge, this poses significant challenges for the application of PCK frameworks. As by definition, the concept of PCK is predicated on teachers' ability to amalgamate content knowledge and pedagogical knowledge in a way to enhance student learning.

From a pedagogical perspective, D&T is said to be characterised by a pedagogy where there is no 'right answer' but rather different responses to the same problem are valued, some more than others (Banks et al. 2004). Spendlove (2012) highlighted that working in a space bereft of explicitly defined content knowledge as a unique advantage of D&T education, in that ownership lies with the teacher, who can in turn draw upon their own interests, their students' interests, and recent developments in the field to engage learners with relevant concepts when required. If there is consensus between the goals of D&T as espoused in curricula and conceptions of capability implicitly held by teachers, then this is true. On the other hand, the possible variability in practices afforded through autonomy of this nature may be problematic, as teachers' implicit conceptions of capability have a greater influence on the nature of activity students engage with, particularly if these implicitly held conceptions do not align with intended learning outcomes. In D&T education therefore, understanding teachers' implicitly held beliefs about the nature of D&T and the nature of activity in D&T is of interest in understanding enacted practices.

There are three elements from the review of the nature of D&T education that should be taken as point to note. Firstly, it is important to outline the commonality between the goals of D&T as depicted in the extant literature and studies. Each identified that educational goals in the discipline are not exclusively knowledge based and that there are a variety of problem-solving aptitudes, value-oriented perspectives, as well as manipulative skills that are necessary to be considered technologically capable or literate. Secondly, the implicit and variable nature of knowledge in D&T suggests that defining specific knowledge for D&T curricula may not be appropriate, as design and technological activity is defined by its application of "provisional knowledge" (Kimbell 2011, p. 7). Williams argues that "the domain of knowledge as a separate entity is irrelevant; the relevance of knowledge is determined by its application to the technological issue at hand. So the skill does not lie in the recall and application of knowledge, but in the decisions about, and sourcing of, what knowledge is relevant" (2009, pp. 248–249). Lastly, from the precarious nature and subsequent application of D&T concepts to various contexts, the level of autonomy afforded to teachers in the discipline needs to be understood in terms of individual teachers' pedagogical aspirations for learning in D&T. This approach may provide useful insight on the assimilation of goals from reformed curricula to enacted practices. From this, pedagogies which align with specific goals may be identified or developed, as although teachers' beliefs and value system will have a profound effect on the nature of teaching in any discipline, the dynamic nature of goals in D&T increases potential variances between teachers. Furthermore, the disciplines legacy issues which have traditionally stifled the development of practice in aligning with reformed policy (Dakers 2005b) highlight the need to understand the relationship between conceptions of capability espoused in reformed syllabi and conceptions of capability held by teachers, thus informing understandings of enacted practice.

Contemporary understandings of PCK

In categorising the multitude of conceptions of PCK in the science education community, Gess-Newsome (1999) highlighted researchers' tendency to view the construct as either an integrative or transformative knowledge category. The integrative category aligns with the concept as first introduced (Shulman 1986), in that PCK is viewed as the 'amalgamation' of other knowledge categories [e.g. general pedagogical knowledge and content knowledge (Shulman 1987)]. On the other hand, a transformative conception views PCK as a separate knowledge base with its own unique identifiers. Models based on the transformative category view PCK as the result of the transformation of knowledge from other knowledge categories [e.g. knowledge of curriculum, assessment and instructional strategies (Magnusson et al. 1999)]. More recently, criticisms have emerged of such fields of thought, and questions have been raised about the relevance of debate between transformative and integrative models of PCK (Kind 2009, 2015). Central to the concerns raised is the apparent disjunction between PCK research and understandings of enacted practice, a trend that has seen researchers call for PCK research that is more predictive of enacted practice (Abd-El-Khalick 2006). With this, concerns pertaining to the nature of PCK are often related to the foundational or applied methods by which PCK has been studied, as many of the methods developed have undergone scrutiny; either due to their inability to capture PCK in an ecologically valid manner, or criticisms have been founded on a lack of topic-specificity in the instrument design. Thus, resulting in the capture of both pedagogical and content knowledge (as well as several other professional knowledge bases) however, the intricacies of PCK are often believed to have been misinterpreted (Friedrichsen et al. 2010) or not captured at all (Kirschner et al. 2015). Further to this, the difficulties in validly and reliably capturing PCK appear to have stemmed from the assertions that PCK is topic-specific (Mavhunga 2012). Veal and MaKinster (1999) first introduced the concept of topic-specificity through establishing a PCK taxonomy which centred on three different levels; general PCK, at a disciplinary level; domain-specific PCK at the level of sub-discipline; and, topic-specific PCK. However, the tiered description of PCK based on topic-specificity leads to more pragmatic questions about the nature of PCK itself and how to capture it validly. Firstly, it is unclear the degree to which 'general PCK' can in fact be generalised amongst teachers as it is not clear if an instrument that does not necessitate the engagement of topic-specific knowledge has the capacity to capture PCK (Schneider and Plasman 2011). Secondly, if a topic-specific instrument situated in teachers' practices is utilised, for example, using the content representations (CoRe) instrument developed by Loughran, Berry and Mulhall (2006), the degree to which topic-PCK is representative of a teacher's everyday practices is difficult to ascertain, as a topic-specific depiction is specific to that educational context.

In an effort to synthesise understandings of the concept of PCK and address the emerging contentions presented above, attendees at the summit on PCK research in science education (BSCS 2012) developed the consensus model of teacher professional knowledge and skill (Gess-Newsome and Carlson 2013). The model (Fig. 1) categorises

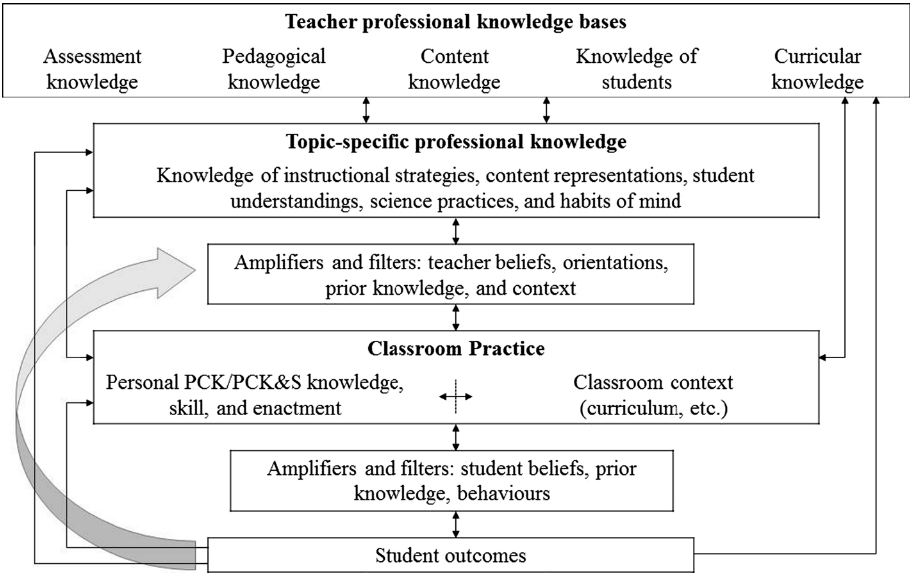

Fig. 1 Model of teacher professional knowledge and skill including PCK (Gess-Newsome and Carlson 2013)

three different types of teacher knowledge; teacher professional knowledge bases (TPKB), topic-specific professional knowledge (TSPK), and PCK. TPKB are defined as general (not content specific) knowledge bases for teaching, such as knowledge of assessment or general pedagogical knowledge. As knowledge bases, these are normative and can be used to construct assessments to quantify what teachers know. TSPK on the other hand, is knowledge that has been codified by experts in a discipline as being important to student learning; a public understanding held by a teaching community. Gess-Newsome (2015) asserts that an example of this type of knowledge would be the content of a CoRe (Loughran et al. 2006), as the CoRe instruments represents how a community of teachers think about how to teach a particular topic to a particular grade level. In contrast to TPKB and TSPK, which are both canonical in nature and held in the profession itself, PCK is recognised as being personal knowledge held by individual teachers. Attendees at the summit define PCK as "the *knowledge* of, *reasoning* behind, and *planning* for teaching a particular *topic* in a particular *way* for a particular *purpose* to particular *students* for enhanced *student outcomes*" (Gess-Newsome 2015, p. 36). The dichotomous implications of defining PCK to a level of context and topic-specificity is noted by Garritz:

> On one hand, it means that PCK must be reconstructed specifically each time a given teacher, within set objectives, has to present a certain topic to a specific set of students with a distinctive background and learning characteristics. On the other hand, it represents a superb challenge, being that PCK is an academic construct that represents an intriguing idea, rooted in the belief that teaching requires much more than delivering content knowledge to students, involving designed purposes and the best ways to represent and evaluate that knowledge.
>
> (2014, p. 733)

From this definition it becomes clear that PCK is no longer considered as a general knowledge base of teachers, nor an individual teachers knowledge, PCK is situated in a specific teacher's experiences. This is supported by the consensus that PCK and associated classroom instruction vary by topic, particularly across topics with different levels of content knowledge (Carlsen 1993) and for topics within and outside areas of content expertise (Hashweh 1987, 2005). In introducing this model of PCK, Gess-Newsome (2015) noted that PCK can be found in the instructional plans that teachers create and in the reasons behind their instructional decisions. This is the knowledge that teachers bring forward to design and reflect on instruction. From this, the relationship between teachers' PCK and practice is theorized to be inherently complex as the interplay involves both knowledge-on-action and knowledge in-action (Park and Oliver 2008). Although knowledge-on-action is relatively easy to explicate as it can be elicited directly from teachers, knowledge-in-action is both enacted and developed during teaching by reflection-in-action (Schön 1983), illustrating the reciprocal dependency between PCK development and PCK enactment (Barendsen and Henze 2017). The implications of situating PCK in practice highlight difficulties in measuring PCK in a normative form, as quantitatively representing the subtle and fine distinction between different forms of teacher knowledge has lead researchers to question whether or not this is a valid enterprise (Gunstone 2015).

In considering the application of the consensus model of teacher professional knowledge and skill in the context in D&T education, an additional degree of complexity emerges. As previously noted, defining specific context *for* D&T negates engagement with the higher order cognitive and attitudinal abilities which the discipline now seeks to develop. The conceptually oriented agenda therefore affords teachers greater influence regarding decisions around 'what' to teach in every day learning activities. This is supported by previous attempts to apply the CoRe tool (Loughran et al. 2006) to D&T education (Williams et al. 2012; Williams and Lockley 2012). In a comparison to a partnership between researchers, practitioners and content experts in science education, a D&T team of the same composition found it challenging to identify specific 'key ideas' for lessons in D&T. The additional negotiation and justification of principles in D&T was theorised to have stemmed from the fact that there was no schema that was familiar to all D&T participants. As in comparison to science education, which has a well-established epistemology, leading to an established organization of knowledge into accepted topics of inquiry, which in turn facilitates common teacher interpretations and representations of content, concepts and appropriate pedagogies (Williams et al. 2016). This study highlights a fundamental difference between the nature of scientific and technological knowledge, and it confirms that methods used to study PCK cannot be universally transferred between disciplines (De Miranda 2018). Therefore, perhaps one of the most significant challenges facing D&T research is then in understanding the pedagogical transmission from intended learning outcomes depicted in syllabi to teachers' enacted practice. With this, vocational education had a commonly understood practice, often being compared to the master apprentice model of the medieval guild (Banks 2000), however, with the emergence of a new agenda for D&T education it is "inappropriate for orthodoxy to become uniformity" (Barlex 2015, pp. 158–159). Therefore, and as the concept of PCK in itself may not be sufficient in exploring the factors which affect D&T teachers' enacted practice, the following section proposes a model centred on enacted practice in D&T education.

Reconceptualising PCK research in D&T: understanding enacted practice

In considering the application of PCK frameworks to D&T education, several contentions emerge. Paramount amongst these contentions is the nature of activity in D&T, as the volition afforded by loosely classified and loosely framed content knowledge boundaries facilitates educational agendas that are specific to individual teachers. This freedom has been framed as a unique advantage of the discipline (Spendlove 2012) and although the conceptually focused composition of D&T curriculum will allow D&T teachers' beliefs to have a greater influence on enacted practice, a significant challenge emerges if individual teacher's educational agendas are not aligned with the outcomes prescribed in D&T curricula. In light of this, the following section presents a methodological framework to explore the relationship between teachers' knowledge, teachers' beliefs and amplifiers and filters of enacted practice in D&T education.

PCK, teacher beliefs and enacted practice

The relationship between PCK and teachers' beliefs is much contended in the PCK research community (Friedrichsen et al. 2010). Despite the initial conceptualisations of PCK considering the concept as exclusively a knowledge base (Shulman 1987), the consistent re-emergence of PCK models containing constructs related to teachers' beliefs (Anderson and Smith 1987; Grossman 1990; Magnusson et al. 1999; Park and Chen 2012) suggests the importance of this construct in influencing teachers' practices. Referring to teachers' beliefs about the purposes and goals of teaching a subject, constructs related to teachers' beliefs are perceived as being influential due to their regulatory relationship between teachers' knowledge bases and PCK. Magnusson et al. (1999) indicate that teachers' beliefs serve as the "conceptual map" (p. 97) that guide instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning (Borko and Putnam 1996). However, similar to research on the nature of PCK, research exploring teachers' beliefs has been marred by different conceptualisations of the position of beliefs relative to PCK and enacted practice. For example, researchers have used terms such as teaching orientations or conceptions of teaching to describe teachers' beliefs about teaching and learning. Anderson and Smith (1987) initially proposed the term orientations to describe teachers' "general patterns of thought and behaviour related to science teaching and learning" (p. 99). Similarly, Hewson and Hewson (1987) describe conceptions of teaching science as a "set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature of content of science and the learners and learning which the teacher uses in making decision about teaching, both in planning and execution" (p. 194). Hewson and Hewson (1987) also suggested that prospective teachers' conceptions of science teaching are reflective of their experiences as students. With their model of PCK, Magnusson et al. (1999) used the term orientation to refer to "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97). Subsequent to these varying conceptualisations, many researchers have noted the interchangeable use of terms such as orientations, dispositions and conceptions (Anderson et al. 2000; Koballa et al. 2005). Although researchers have used the terms conception, belief, disposition, and orientation interchangeably, common themes have emerged that are of importance to understanding enacted classroom practices and its relationship to PCK; prospective teachers enter teacher education programmes with strongly held beliefs about teaching and learning (Anderson et al. 2000; Koballa et al. 2005); these beliefs are resistant to change, although they can be changed and are perhaps most susceptible to change in teacher education or the earlier years of a teacher's career (Magnusson et al. 1999; Simmons et al. 1999); and, experienced teacher beliefs consist of multiple central and peripheral goals which may shift based on the course, topic and grade-level of the student (Friedrichsen and Dana 2003).

In an effort to synthesise current understandings of the terms, Friedrichsen et al. (2010) conducted a literature review of uses of the term 'orientations' in the PCK research community. In their paper, they highlighted four methodological issues with the use of the term: (a) using orientations in different or unclear ways, (b) unclear or absent relationship between orientations and other PCK model components, (c) simply assigning teachers to one of the nine categories of orientations theorised by Magnusson et al. (1999), and (d) ignoring the overarching orientations component. In an effort to progress the orientations agenda, Friedrichsen et al. (2010) summarised their review in presenting a model for future research in science education (Fig. 2). The presentation of the model was perceived as the first stage in developing conceptual and methodological clarity regarding orientations. In introducing the model of teacher professional knowledge and skill (Fig. 1), Gess-Newsome (2015) detailed that the knowledge held in both the TPKB and TSPK components of the model are canonical in nature and held by the profession itself, and although this knowledge is accessed by individual teachers in order for it to be personalised, "it must pass through the lens of the teacher" (Gess-Newsome 2015, p. 34). The autonomy afforded to teachers in their selection and implementation of pedagogical approaches is described as being mediated by teacher's beliefs and orientations. Situating beliefs in the intermediary between teachers' knowledge bases and enacted practices, or as an amplifier or filter of practice, affords the opportunity to better understand enacted practices, as this organisation of teacher knowledge is cognisant that teachers' beliefs have the potential to affect practice in a variety of ways.

In acknowledgement of Settlages' critique of PCK as traditionally being bound to its knowledge-as-commodity construct and the relatively little regard given to what teachers actually do (2013), the authors propose that a model concerned with better understanding enacted practice must centre on exploring enacted practice, cognisant of both teacher knowledge and beliefs. In contrast to the model presented at the PCK summit (Fig. 1), it is theorised that teachers' beliefs will have a greater influence than the mediation between

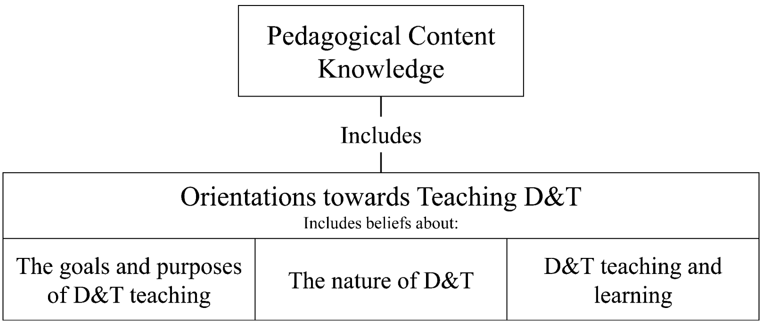

Fig. 2 Model of orientations towards teaching from Friedrichsen et al. (2010) adapted for D&T education

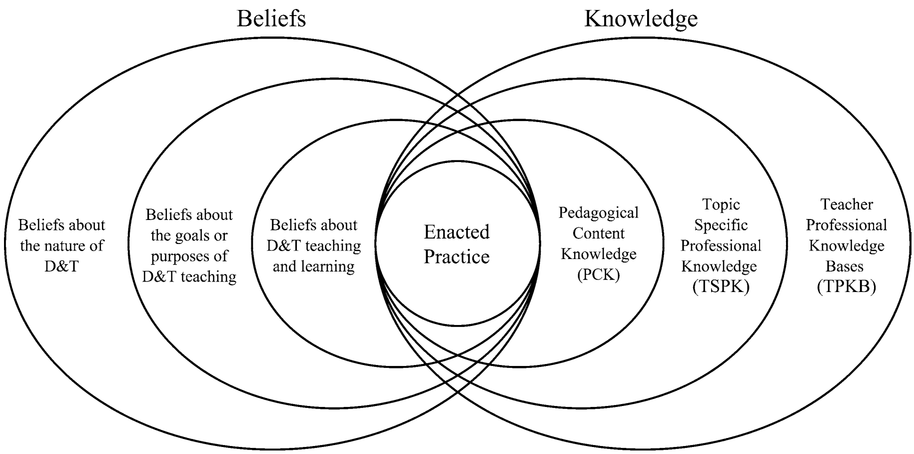

Fig. 3 Theoretical model of enacted practice, teachers' beliefs and teacher knowledge

teachers' knowledge bases and enacted practice. In particular when considering the nature of D&T education as presented earlier, the freedom afforded to teachers is increased through the lack of a commonly agreed upon epistemology in the discipline. In other words, before a teachers' knowledge in D&T is mediated by how to teach and why, they must decide what to teach. The framework proposed by Friedrichsen et al. (2010) is perceived to be of particular use here as it not only considers pedagogical and epistemological elements of teachers' beliefs, but also their ontological beliefs specific to the nature of the subject. The theoretical model presented in Fig. 3 helps to represents the interactions that occur between teachers' beliefs and knowledge in D&T education, and the centrality of enacted practice. The framework synthesises the three knowledge bases proposed at the PCK summit (Gess-Newsome 2015) with the orientations framework proposed by Friedrichsen et al. (2010). Critically, as opposed to being a model of PCK, the researchers view this as a model of enacted practice in D&T and utilise the concept of PCK for its explanatory power in depicting the intricacies of everyday practice.

Paramount amongst beliefs in the model are teachers' beliefs about the nature of D&T. These beliefs, which may be described as teachers' conception of capability, are of critical importance in understanding enacted practice in the discipline. The need to understand these beliefs stems from both the recent reformations in the discipline internationally, and the freedom afforded to teachers through loosely defined content knowledge boundaries. The influence that individual conceptions of capability may have on practice is supported by the work of Dow (2004, 2006, 2014), where it was identified that D&T teachers' intrinsic conceptions of what is important to learning in the discipline are generally accepted as being difficult to change and strongly influences by their own educational experiences. Furthermore, from a curriculum perspective, Porter (2006) discussed the various influences on teachers' pedagogical decisions, identifying that teachers may choose to teach content for a variety of reasons, such as what they believe to be most important, what they think students are ready to learn, or what is most enjoyable for them to teach. On a similar note, the traditionally vocational nature of D&T education may be problematic from the perspective of the recent reformations of the discipline as such reformations may necessitate a shift in teachers' conception of capability to align with reformed syllabi. Investigating the degree of alignment between conceptions of capability held by teachers in the discipline and capability as espoused in syllabi may offer an explanation of the disjunction between rhetoric and reality in D&T (Barlex 2000; Kimbell 2006). From the perspective of research concerned with understanding enacted practice, identifying D&T teachers' conceptions of capability may be seen as the first step in a methodological approach to understanding enacted practice, as this approach remedies extant issues with the perceived lack of explanatory power with existing theoretical conceptualisations of PCK. It is of interest then to understand the formulation of teachers' conceptions of capability, and a valid and reliable manner by which conceptions may be captured. It is also important to note that a teacher's beliefs are not necessarily a static entity, and although one's beliefs may evolve, the mediation of actions by teachers' beliefs in different educational contexts offers an explanation of apparently contrasting depictions of an individual teachers' PCK. Relative conceptions may be ascertained through the application of tools such as the CoRe (Loughran et al. 2006) or the application of a learning study approach (Nilsson and Vikström 2015). Ascertaining true conceptions may be more difficult, and somewhat counterintuitively it may be appropriate to separate the instrument from teachers' everyday practices.

From proposing a conception of capability approach to exploring enacted practice, two pertinent issues emerge. Firstly, and as evidenced earlier, D&T as a discipline has traditionally struggled for identity in the curriculum, based on the lack of a common agenda. Achieving consensus on or determining the reasons for differing conceptions of capability in the research community appears to be the logical first step in understanding practice. Such findings may then be used as a barometer by which individual teachers' conceptions may be compared. The ontology of goals developed by Rossouw et al. (2011) may provide a useful starting point for research to this end. Secondly, it is important to note that teachers' conceptions of capability are inherently a dynamic entity, much like the disciplinary goals from which they are optimally derived. In a discipline predicated on its adaptability and continual evolution, identifying conceptions of capability at a particular point in time will undoubtedly be of use. However, understanding how evolving conceptions manifest themselves in policy and in turn practice should also be of particular interest for future research.

Situational amplifiers and filters of practice

Situating the amplifiers and filters component of teacher professional knowledge and skill (Gess-Newsome 2015) in the intermediary between teachers' knowledge bases and enacted practice offers an explanation to inconclusive findings between teacher PCK, enacted practice and student achievement (Baumert et al. 2010; Gess-Newsome et al. 2017), as the construct identifies the need to understand the various factors which may affect utopian classroom intentions. In considering factors which have the potential to mediate teachers' actions and choices in the classroom, some elements are immediately apparent. For example, Gess-Newsome (2015) highlighted the potential of; teachers' views about the societal goals for schooling, their orientation toward preferred instructional strategies, or their preferred organization of the content of their discipline, all as potential amplifiers or filters of practice. Within this however, there is an important distinction to make between factors which have the potential to affect teachers' practice holistically, such as expectations placed on the teacher in a particular school culture, and more day-to-day factors such as availability of resources. The need for such a categorisation stems from Kennedy's (2010) proposal that the educational research community may be guilty of attributional error, as researchers overestimate the power and influence of teacher personal characteristics and practices. Instead, she proposes that situational forces such as; teachers' work (time, materials, and work assignments), students, school interruptions into the classroom, and the difficulty of attending to multiple reform efforts simultaneously may have a stronger relationship to student learning than teacher quality. This problem of enactment (Kennedy 1999) in teaching practice highlights the need to understand the different frames of reference in which teachers' practices are being discussed. Without an explicit frame of reference for observations of enacted practice, the degree to which generalisations can be made of observations is unclear. This is perhaps more appropriate when exploring enacted practice in D&T education, as the additional variance of increased volition is facilitated by the nature of the subject. This situational frame of reference is depicted in Fig. 4 by means of depicting the importance of understanding the various factors which load on a teacher's practice in a particular instance. The importance in understanding situational amplifiers and filters of practice is predicated on the concept of ecological validity. Exploring enacted practice through situating data collection instruments in the learning context, where data about the context itself may be gathered provides greater opportunities to generalise findings in the discipline.

Systemic amplifiers and filters of practice

Further to this, systemic amplifiers or filters can be characterised by the educational context and subsequent expectations which may be placed on teachers. Here any factor which has the potential to affect teachers' utopian aspirations for classroom practice should be considered. Examples of such may be; a misalignment between intended learning outcomes prescribed in syllabi and a highly performative assessment culture (Porter 2006) which may require teachers to truncate syllabi at the expense of student learning (Hyland 2011). School or departmental ethos or 'standard practices' may also have an impact on teachers' pedagogical aspirations. These cultural factors are important due to their perceived effect on teachers' knowledge and beliefs over a sustained period of time. As with situational amplifiers and filters, the contribution of detailing (or controlling) systemic factors which load on a teacher's practices is essentially that of content validity. Further to this however, it is theorised that systemic amplifiers

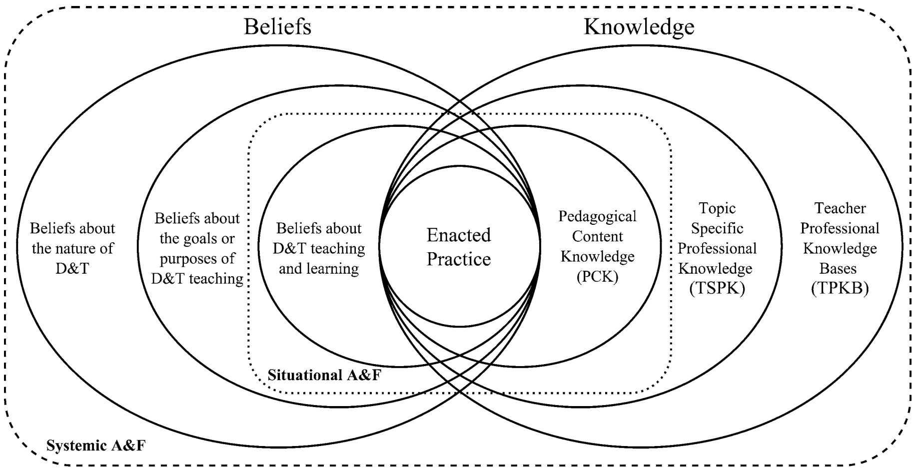

Fig. 4 Ecologically situated model of enacted practice, teachers' beliefs and teacher knowledge

and filters may be of critical importance due to their position as a confounding variable, as work on teacher enculturation (Goodson 1991; Tishman et al. 1993) suggests that expectations of the teaching context may influence teachers' beliefs as more teaching time is spent in a particular context.

The framework identifies the need to understand individual teachers' agendas for D&T education before factors which may act on these agenda can be identified. Triangulating teachers' conceptions of capability for D&T learning, their beliefs about the nature of teaching and learning in the discipline, and their perspective on their enacted practices affords the unique opportunity of a self-reflective depiction of practice in D&T, in the context of student performance relative to a particular context. To affect practices, a conceptual change of teachers' beliefs about the nature of teaching and learning in the discipline may be necessitated. This resonates with the earlier discussion exploring the relationship between PCK as a knowledge base and enacted practice, and offers an explanation as to why a teacher may be reluctant to utilise a particular pedagogical approach. Furthermore, research housed within the framework presented may also provide insight into previous findings in the discipline. For example, Jones and Compton (1998) identified a disjunction between a teacher's understanding of technological capability and enacted practices, as teachers focused on the production of a product rather than the thinking skills, creativity, processes, issues, and key learning involved, where an underdeveloped conception of capability was identified. As the amplifier or filter framework emphasises the importance of identifying and understanding how actors influence conceptions of capability and thus practices, supplementary studies identifying what is deemed by teachers to be of importance may determine the degree of alignment between practices and capability as prescribed by syllabi. This approach frames the dependant, independent and confounding variables to consider the exploration of enacted practice in D&T education.

As the framework presented in Fig. 4 is ultimately concerned with better understanding enacted practice in the discipline, it is important that the framework is read and applied in this way, from the centre out. From this perspective, observations of classroom practice have the potential to elicit teachers' PCK, specific to that educational context. It is important to note that this PCK is not necessarily representative of this teacher's *entire* PCK. Similarly, observations of or reflections on teachers' practice potentiate the elicitation of teachers' ontological beliefs about the nature of the subject. Although these beliefs may not be fully representative of their beliefs about the nature of D&T, their interdependency on enacted practice is the unique contribution of this approach. The amplifiers and filters elements reinforce this contribution as they highlight the need to understand practice from an ecological perspective. Thus, in an effort to investigate practice in the discipline from an ecological perspective, cognisant of the need to simultaneously consider the cognitive and affective factors which affect teachers' actions (Charalambous 2015), the contribution of this research is in proposing a methodological framework to facilitate this investigation. That is not to say that research concerned with individual elements of teachers' knowledge or beliefs will not be of use. However, the nexus of the argument put forward here, is that if generalisations are to be made about the nature of practice in the discipline, researchers must consider all of the factors which have the potential to affect findings.

Conclusion

This article set out to consider the appropriateness of applying PCK frameworks to D&T education, with the ultimate goal of better understanding enacted practice in the discipline. Through an analysis of contemporary understandings of the nature and goals of D&T education, it appears as though the affordances offered by weakly classified and weakly framed discipline boundaries are greater in D&T than many other areas. Although these affordances may have stymied the development of an epistemology of D&T, they are considered an integral element, as a utilitarian agenda governs the use of knowledge in the discipline. It is therefore important to note that defining clear subject boundaries is not considered to be an appropriate solution to understanding the nature of practice, as prescribing content *for* D&T negates the broader aims of syllabi such as the development of technological capability and technological literacy. The difficulties in applying PCK frameworks to D&T may stem from this contention, as contemporary understandings of PCK view the construct as topic-specific. And as relevant knowledge for D&T only becomes apparent through engagement with D&T tasks, this raises questions as to the validity of current approaches in generalising findings from outside the classroom. Furthermore, the relationship between prescribed curricula and enacted practice is not necessarily understood in D&T, and the freedom afforded to teachers highlights the need to understand the influences of teacher beliefs on enacted practice.

The methodological framework presented herein attempts to frame the various elements which influence enacted practice, through recognising the magnitude of teachers' beliefs and distinguishing between situational and systemic amplifiers and filters of practice. First, the relationship between PCK and teachers' beliefs has shared a marred past, as many researchers have debated whether or not beliefs should be considered an element of PCK. The stance taken in this article is that beliefs are not an element of PCK, although their influences on its development and enactment through planning and enacted practice are recognised. Secondly, a recent objective in PCK research has been to explore amplifiers and filters of practice, this article progresses this agenda through arguing the need to understand both situational and systemic amplifiers and filters of practice in D&T. The need for this also stems from the nature of D&T as a discipline and thus, the variances which may impede teachers' intended practices need to be understood. From this, the article argues the need to comprehensively understand the interactions between teachers' knowledge and beliefs, cognisant of both situational and systemic amplifiers and filters, to truly understand the reality of classroom practice. Only then can we comprehensively understand the influences on pedagogical practice and in turn, strategically affect change.

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