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Unpacking secondary school technology teachers' interpretations and experiences of teaching 'problem-solving'

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Abstract

Research relating to the nature and purpose of 'design' activity across education sectors has accelerated in recent years as governments and policy makers throughout the world highlight the importance of skills such as creative problem-solving and innovation. Within secondary schools, responsibility for teaching and learning through design is often assigned to Technology and Engineering subjects, however, gaps tend to exist in relation to what different teachers understand and experience about the teaching and learning of problem-solving and design in their classrooms. In this exploratory study, a small group of practicing secondary school teachers completed a one day training workshop where they were introduced to new knowledge and pedagogical skills relating to design problem-solving using a classroom intervention called 'Designing Our Tomorrow'. The teachers participated in a focus group discussion before and after the workshop in which they discussed their experiences in teaching design. Conceptual Metaphor Theory (CMT) (Lakoff & Johnson Metaphors we live, University of Chicago Press, 1980) was employed to highlight the figures of speech used by the teachers during the focus groups and from these a number of conceptual metaphors were identified that described their understandings and experiences of teaching design problem-solving. In synthesizing the broad theoretical base relating to understandings of design problem-solving and CMT together with the findings from the one day professional development workshop, the paper highlights the potential value for researchers in using CMT to unpack teachers' views on how design problem-solving is taught and learned in schools. Finally, the paper reveals a potential new space to inform and evaluate future professional development of Technology teachers, particularly where the focus is on complex and difficult to define concepts such as design and problem-solving.

Keywords Conceptual metaphor theory · Problem-solving · Design · Creativity · Teachers · Professional development

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Introduction

Design education, and broader education in general, has witnessed a significant shift in the last number of decades to more student-centred, participatory type practices with a human focus where creativity and knowledge are brought together as ‘an engine of school improvement’ (Calavia et al., 2021, p. 2). Within Design and Technology education for example, an identity shift has occurred (Keirl & Barlex, 2009) where there is now a strong emphasis on the design process as a vehicle to enable students to take greater ownership of their learning and facilitate a more investigatory approach to understanding the subject matter (Jones et al., 2013; McGarr & Lynch, 2015; Shanta & Wells, 2020). This approach is considered important for the development and stimulation of young people’s imaginations with a variety of benefits arising from this for both society and the economy (Sternberg et al., 2005). Problem-based learning (PBL) has traditionally been used for decades in schools to achieve this aim within Technology Education.

PBL typically involves presenting students with an ill-defined, real-world problem that is indicative of professional [design] practice; is student centred; involves individual and group work; and involves ‘practice and reflection about the strategies used and the results achieved’ (Carvalho, 2016, p. 35). There is much in common with PBL and historical and contemporary conceptualisations of creativity. For example, some see creativity as a process (Wallis, 1926), more recently, an iterative process (Finke et al., 1992). Others describe a creative process in relation to problem-solving and make the distinction between clearly defined problems (using a more formulaic approach) and ill-defined problems (using a more heuristic approach which involves trial and error) (Weisberg, 2006). Ill-defined problems require creative solutions (Finke et al., 1992) and many solutions to the problem are often possible (Boden, 1990; Cropley, 2001). Commentators in the field of design also talk of problems that are messy, ambiguous and ill-defined (Cross, 2011) as well as the problem space being narrowly defined or more open-ended and thus affording more opportunities for generating many [creative] solutions (Gero, 1993). The fields of engineering and design also suggest that the process of design is iterative as appropriate solutions are explored and developed over time (Cross, 1997; Lawson, 2001). Finally, commentators in the fields of design view creativity as a social process where the interaction with others (including oneself as part of reflection during the problem-solving process) is key to solving problems (Cross, 2011; Glaveneau, 2015).

PBL cannot be considered as an ideal approach for all learning activities, especially if the objective is to memorise new knowledge. This has been highlighted in the work of Hattie (2008) where a low effect size for PBL is shown, while Ginestié (2017) describes the need to have a clear initial representation of a problem in learning situations. However, PBL can be considered an effective method for learning in Design and Technology subjects where problems are often ill-defined and the learning experience involves; discovery, simulation, group work, reflection, student directed learning and problem solving. This is supported by Williams et al. (2008) where they highlight the advantages of PBL in the training of Technology teachers and in the development of technological literacy.

Discussing PBL in relation to the literature on creativity and design is important as it informs a classroom based intervention research project called Designing Our Tomorrow (discussed later) as well as adding some clarity to the authors own position with respect to solving design problems which can be summarised as a social, ill-defined and iterative process that affords many possible solutions. The term 'problem-solving' is used from now on for consistency and this is captured nicely by Cross when he suggests that when solving problems the designer:-

> '…sets off to explore. To discover something new, rather than to reach somewhere already known, or to return with yet another example of the already familiar' (Cross, 2011, p. 8).

However, PBL's application has often been influenced by a quasi-vocational rationale. This vocational rationale can restrict the student experience to perceived relevant outcomes that explicitly align with expected learning outcomes. This can often be to the detriment of more long-term, less obvious experiences within design education that may appear at first glance tangential. For example, many Design and Technology educators have reported how problem-solving is reduced to being ritualistic, 'with lessons structured around a series of steps' controlled by the teacher, leading to the same outcome as this 'does not necessarily affect the students thinking' (McCormick, 2004, p. 26).

Consequently, teachers of Design and Technology subjects may also use the design process as a way of structuring the student learning experience, but still adopt a very teacher-centred approach to their teaching. This is supported by recent work by Calavia et al. (2021) where they describe persistent methodologies where the teacher etches information on the blank slate of the student. There is international evidence of this kind of practice within D&T education and other subjects stretching over a period of time (Nicholl & Spendlove, 2016; Renzulli et al., 2003; Stables, 2017; Williams, 2017). Commentators suggest however that creativity cannot be reduced to teaching via a series of steps in this way (Amabile, 1996; Boden, 1990; Weisberg, 2006). For that reason professional development (PD) has aimed to challenge teachers' conceptions of problem-solving in order to help them to integrate it into their classroom practices in a more meaningful and authentic way. With this in mind, the core goal in education for PD is for it to a lead to a positive impact on the participating teachers and ultimately their students' learning experiences (Vansteelandt et al., 2020).

Such PD experiences are frequently evaluated by seeking the teachers' views and insights gained from the professional workshops or from capturing their future practices (King, 2014). While PD has been shown to have had an impact on the classroom experience of students and teachers, the extent to which PD programmes have contributed to teachers' reconceptualisation of their practice can be challenging. For example, teachers can frequently report positively on the experience (to appease assessors and course providers) and are likely to recognise what they *should* say, based on the content and focus of the PD. Further still, if teachers' practices are observed in classrooms to evaluate changes in their practices, teachers may adopt practices in a superficial manner without an appreciation and recognition of the educational rationale for the action (Donnelly et al., 2014). Researchers therefore need to explore the use of alternative approaches to examining the impact of PD activities on teachers' beliefs and practices. One possible approach is the use of Conceptual Metaphor Theory (CMT).

With this in mind, this paper reports on a small-scale, exploratory study developing Technology teachers' pedagogical strategies to develop students' problem-solving capabilities. While undertaking an analysis of focus group interviews to evaluate the workshop, it was apparent that the teachers drew on different conceptual metaphors to describe their practice. While not the primary focus of the research project, the use of these conceptual metaphors led the research team to explore this further by examining the range and frequency of the metaphors employed and this is the focus of this paper. This was considered both a novel way to explore teachers' beliefs around problem-solving in secondary school and in evaluating the impact of the PD workshop. As a result, the research was guided by two research questions, namely:

1. In talking about the teaching of problem-solving in Technology subjects, what conceptual metaphors did the teachers draw on?
2. Following completion of the workshop, was there a change in the conceptual metaphors employed by the teachers when talking about problem-solving?

Before outlining the study methodology, Conceptual Metaphor Theory (CMT) is described in more detail in the next section.

Conceptual metaphor theory

Conceptual Metaphor Theory (CMT) refers to the process of understanding one idea in terms of another. CMT is grounded in cognitive linguistics and its emergence in the early 1980s has been cited as a major revolution in the study of metaphor (Gibbs 2011). In their seminal work on CMT, Lakoff & Johnson (1980) describe how much of our everyday thinking involves conceptual metaphors and we use metaphors in our language to make sense of our experiences. Metaphors are viewed by Lakoff & Johnson as a device that enables the 'poetic imagination' in turning ordinary language into extraordinary language. They are pervasive in all aspects of life, not just in the language used by people but also in their thoughts and actions. Metaphors are not just abstract figures of speech, but an 'essential mechanism of the mind' (Martínez et al., 2001, p. 965).

The metaphors that people employ are shaped by their culture and they are often embedded and shared within communities and should be studied within their socio-political context (Refaie, 2003a, 2003b). Metaphors provide an insight into ideas that are not explicitly or consciously held and their use can be examined in mapping connections that might not have been made through the use of direct questions (Kim & Maher, 2020; Leavey et al., 2007). Research in cognitive linguistics suggests that several hundred basic conceptual metaphors probably exist across different languages and cultures (Gibbs 2011; Kovecses, 2002; Lakoff & Johnson, 1999; Yu, 1999).

An example of a conceptual metaphor drawn from the work of Lakoff & Johnson is 'Argument is War' where 'argument' is the overarching concept. By viewing the statement below through the conceptual lens of Argument is War, 'argument' can be viewed as being metaphorically structured or talked about in terms of war and therefore the language is metaphorically structured (Lakoff & Johnson, 1980). The following are some examples of figures of speech aligned with the Argument is War conceptual metaphor.

- Your claims are *indefensible*.
- He *attacked every weak point* in my argument. His criticisms were *right on target*.
- I *demolished* his argument.
- I've never *won* an argument with him.
- You disagree? Okay, *shoot*!
- If you use that strategy, he'll *wipe you out*. He *shot down* all of my arguments.

Other examples from Lakoff and Johnson (1980) include: TIME IS MONEY—'You're *wasting* my *time*'… *LOVE IS A JOURNEY*— 'This relationship is foundering'… and THEORIES (and ARGUMENTS) ARE BUILDINGS—'Is that the foundation for your theory?'.

Metaphors can play a powerful role in shaping our perception of events. People have experiences for which they develop conceptual metaphors to make sense of that experience (Alger, 2009) and they then use these metaphors to make sense of new experiences. Lakoff & Johnson (1980) describe how metaphors can be used as a tool to better understand people's views towards abstract concepts. Researchers are now using CMT to examine embodied conceptions and knowledge in order to understand the origins of these conceptions and the development of external representations (Niebert & Gropengiesser, 2015). People will often use metaphors that have a deep personal connection for them and these conventional metaphors will often be shared by others within the same community or culture. For this reason, CMT is now considered a good way of exploring teachers' understanding of their practice.

Teachers use metaphorical language frequently when discussing and describing their views on different students, their own teaching approaches and their profession. Metaphor analysis is used in school based research as a tool for unpacking the undisputed prevailing views of teachers and students relating to different subject areas. In their work with experienced and prospective teachers, Martinez et al. (2001) used co-reflection to examine teachers' metaphorical conceptions of learning. Using this approach, they were able to categorize teachers' conceptions of learning and teaching as either behaviourist – 'Learning is like a video camera which records the world', constructivist – 'Learning is a detective who looks for things and into things', or situative – 'Teaching is like a tourist guide who negotiates a route with the tourists'. Alger (2009) and Leavy et al., (2007) also used metaphorical analysis to examine teachers' beliefs about teaching and learning at different stages of their career. Using CMT, Yee (2017) found a coherent set of metaphors that could be used to provide a discursive space for students and teachers to discuss problem-solving in Mathematics in a concrete way. Similarly, Thomas and Beauchamp (2011) examined the metaphors used by teachers to describe their professional identity at the early stages of their careers. They found that the development of teacher identities can be gradual, complex and problematic and using metaphor analysis they observed how teachers made a shift from seeing themselves as ready for the challenge at graduation stage and quickly adopting to a survival mode early in their first year of full-time teaching.

The importance of problem-solving across different school subjects is well documented and it also has an important role in Technology subjects. Numerous studies have examined the nature of problem-solving in Technology subjects and the role played by metaphorical, analogical, and divergent modes of thinking (Hey et al., 2008; Lewis, 2008). However, there is little evidence of any research that has attempted to unpack teachers' beliefs and understandings about problem-solving relating to design activity and the impact, if any, that professional development courses have on this. Therefore, the purpose of the study described in this paper was to examine practicing Technology teachers' beliefs about problem-solving in their subject area using Conceptual Metaphor Theory (CMT).

Context of the study

Irish post-primary education caters for students from the ages of 12 to 18 years of age and is divided into a junior cycle course (12–15 years) and a senior cycle course (16–18 years) of study. Students complete the Junior Certificate and Leaving Certificate through the completion of different subject areas (some compulsory and some optional). Assessment of the

Junior Certificate is undertaken through both school-based work and externally assessed examinations held at the end of the 3 years. The Leaving Certificate programme is assessed via end of programme examinations that are externally set and assessed by the State Examinations Commission (SEC). Most subjects include some school-based project work as well as terminal examinations. Technology-related subjects include such project work where students are given a 'real-life' brief or problem to solve such as designing a children's toy, as well as preparing for written terminal examinations. A students' performance in the Leaving Certificate determines entry into third-level education, and as a result, senior cycle education in post-primary schools has been criticised for several decades as being too examination focused (Lynch et al., 2013). This focus on the terminal exams, and achieving the highest grades possible, has arguably stifled pedagogical innovation and shaped how students experience subjects particularly in the coursework elements of the examination process discussed previously. The authors are aware that there might be many reasons for teacher's struggles with teaching ill-defined problems not least the competing tensions between performativity and creativity (Nicholl & McLellan, 2008) but thought it would be worthwhile to explore problem-solving as part of teachers' professional development in the Irish context.

Technology education in Irish schools is addressed through the provision of a number of subjects. At senior cycle level there are the subjects of Engineering, Construction Studies, Technology, and Design and Communication Graphics. The provision of such a set of subjects, that have significant overlap in content, is a result of their historical craft-based origins which have remained influential throughout the decades, despite efforts to integrate a stronger design and problem-solving approach to the subjects along the lines discussed above. This pattern is common throughout the world in Technology subjects in secondary schools where many countries are attempting to balance the goals of vocational versus general Technology education (Jones et al., 2013). Hence, while the subjects at an official curriculum level espouse a design-based philosophy and a strong focus on creative problem-solving, students' experiences of the subject tend to reflect the more craft-based traditions. It is within this context that the current study was implemented.

Methodology

Designing our tomorrow (DOT): an overview

Designing Our Tomorrow (DOT) is a collaboration between the Faculty of Education and the Engineering Department at the University of Cambridge (Demetriou & Nicholl, 2021; Nicholl, Flutter, et al., 2013; Nicholl, Hosking, et al., 2013; Nicholl et al., 2013). DOT challenges students to find and solve real-world problems.

Although DOT starts with a challenge in the form of an ill-defined problem, it has also identified and developed a range of [design] psychological tools which become the signature pedagogies that 'form habits of mind, habits of heart and habits of the hand… signature pedagogies prefigure the culture of professional work and provide the early socialisation into the practices and values of the field…the way we teach will shape how professionals behave' (Shulman, 2005, p. 59). Using Vygotsky's socio-cultural theory of development, historically, the tools that have socialised students within D&T education have focused on the tools of labour (e.g. workshop tools such as hammers, saws and more recently digital tools) that enhance human's practical capability. This narrow focus on the tools of labour means children are not given the opportunities to master the 'psychological tools' (thinking and problem-solving strategies) used by engineers and designers as, 'it is "cultural heredity" provided to a child through mediation that determines to a great extent how the child develops' (Karpov, 2014, p. 11). According to Vygotsky, once the psychological tools have been mastered 'they mediate the [higher] mental processes' that are necessary for solving problems (Karpov, 2014, p. 17). Furthermore, Vygotsky stressed that these experiences were socially mediated, for example interactions between teachers and peers, or peers to peers (Moran & John-Steiner, 2003). There is an increasing body of evidence supporting this, in particular, the crucial role that different types of dialogue as part of the socio-cultural practices within a classroom can play in a child's intellectual development (Alexander, 2004; Mercer & Littlejohn, 2007).

This theoretical overview locates DOT within a social constructivist paradigm which is consistent with Vygotsky's socio-cultural theory which contends 'whilst knowledge is personally constructed, the constructed knowledge is socially mediated as a result of cultural experiences and interactions with others in that culture' (McRobbie & Tobin, 1997, p. 194). Social constructivism with its emphasis on learning and development through adult mediation via socio-cultural practices makes it different to other learning and development theories as Karpov states:

> 'children's learning and development are neither predetermined by heredity, as nativists hold; nor determined by conditioning, as behaviourists hold; nor the result of children's independent explorations as constructivists hold. Rather, children's learning and development in age-appropriate activities, in the context of which adults promote the development in children of new motives and teach them new thinking, problem solving, and self-regulation.' (Karpov, 2014, p. 9)

For DOT, the teacher is key, as they provide the learning experiences for children studying D&T in order to develop intellectually. To this end, DOT has identified and developed a range of psychological tools and cultural practices used by designers/engineers that provides the 'cultural heredity' that is absent from many D&T classrooms but is crucial for a child's intellectual development. These tools and wider cultural practices are to support the teacher in mediating students so they can reach their intellectual potential.

This discussion provides a context from which the current study took place in the Republic of Ireland, where in many ways, the narrow focus on the tools of labour that focus on achieving an outcome apply. Recent changes to Technology subjects in the Republic of Ireland (discussed earlier) requires a shift not only in what is taught (problem-solving skills) but the way it is taught (socially mediated). As teacher educators, the authors appreciate that teachers also need help and support in the form of regular professional development, so they feel comfortable and confident with changes to their current practices when faced with new initiatives such as DOT. To this end, 4 practicing teachers were invited to a one-day PD workshop where they were introduced to a range of psychological tools and cultural practices developed to help practicing designers and engineers design more inclusively for an ageing population (for further details about DOT and inclusive tools and practices see Demetriou & Nicholl (2021)). This research reports on the experiences of the 4 teachers before and after their professional training in order to obtain their views about teaching of problem-solving with respect to recent curricula developments in the Irish context. The focus on the teacher was a conscious decision as they are the 'gatekeepers' with respect to teaching for problem-solving (Csikszentmihalyi, 1999; Nicholl & McLellan, 2008). Providing teachers with the opportunity to discuss their views would provide insights into how these teachers managed with making the transition to transform their own practice and inform future PD of teachers in the Irish context.

Training day

Study participants

A recruitment email was circulated to over 600 practicing Technology teachers in Ireland explaining the details of the study and over 50 expressions of interest were received. A number of factors were considered in the criteria to select teachers including; their availability to attend a one-day training workshop at the host institution, willingness to incorporate a ten-week series of activities into their school classroom and their willingness to engage with the research team throughout to provide feedback on their experiences with the DOT activities. Four teachers (one female and three male) were selected for participation and this number was capped due to the limited budget for the study which was supported by a seed fund from the Teaching Council (which is the professional standards body for the teaching profession in Ireland). All teachers had between 5 and 15 years of fulltime experience teaching Technology subjects in secondary schools and all four schools were mixed-sex schools.

While this study only involved one female participant, it is representative of the low number of female Technology teachers in Ireland. Ethical approval for the study was granted by the research ethics committee at the host institution.

Formal workshop

The formal training for the day was facilitated by a member of the research team who is one of the founders of the Designing Our Tomorrow (DOT) intervention. Each participating teacher was provided with a toolkit containing a range of tools and classroom resources for teaching creative problem-solving in their secondary school classroom. The theory underpinning the philosophy of DOT was presented first to the teachers and this was followed by an exploration of different learning activities throughout the day. The primary focus of the training was on unpacking different ways of viewing and exploring design problems with a specific emphasis on the psychological tools and cultural practices that can be utilised in a secondary school classroom. Some examples of the activities explored included the use of restrictive gloves to mimic difficulties that a person with arthritis might encounter when manipulating objects, and the use of blurred goggles to allow the user to appreciate the difficulties encountered by people with impaired vision when reading maps (Fig. 1). Further details relating to the formal teacher training for DOT can be found in Demetriou & Nicholl (2021) and Nicholl et al. (2013).

Pre and post workshop focus groups

At the beginning of the DOT training day, the four teachers were introduced to each other and to the research team. Before engaging in the formal training, the teachers engaged in a focus group discussion in order to unpack and share their thoughts around problem-solving in the classroom. While the focus of the current study was on examining the metaphorical conceptions that the teachers had in relation to problem-solving, the discussion was framed so that the teachers could discuss their thoughts in a relaxed

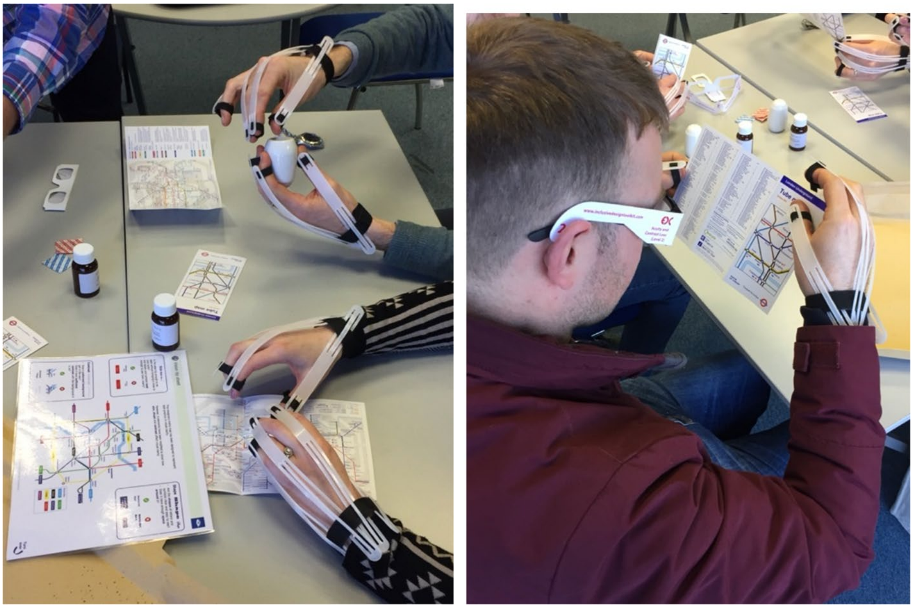

Fig. 1 Exploring the Designing Our Tomorrow (DOT) activities during the formal workshop

fashion with their peers who have shared experiences of similar cultures and communities (Refaie, 2003a, 2003b). This then enabled the researchers to subsequently examine the discussions through the lens of Conceptual Metaphor Theory (CMT) when the training day was complete.

The guiding questions for the pre-workshop discussion were as follows:

1. What does problem-solving mean for you?
2. Is problem-solving relevant in the school curriculum? Is it relevant in your subject area?
3. What strategies do you currently use in your teaching to develop pupils problem-solving skills?
4. Do you experience any challenges when teaching activities that involve problem-solving? How do you overcome these challenges?

At the end of the six-hour training day, the teachers participated in a second focus group discussion where the primary focus was on establishing if the teachers' views and beliefs around problem-solving had changed in any way. The following were the guiding questions:

1. Has your understanding of problem-solving changed in any way for you in light of the training day?
2. What are your thoughts now on the relevance of problem-solving in your subject area and across the school curriculum?
3. Will you bring back any of the strategies you learned today to your classroom? If so, how do you think they might help in developing problem-solving skills?

4. What challenges and opportunities do you anticipate for problem-solving in your classroom using DOT? How might you overcome these challenges and embrace the opportunities?

Analysis of data

The data for this short study comprised two focus group transcripts that were transcribed verbatim. The analysis of the data took place in the following stages:

1. The transcripts were independently analysed by two of the primary researchers on the study in order to highlight any metaphors that were recorded during the conversations. The examination of metaphors as blueprints of thinking about learning and teaching through a process of co-reflection is advocated by Martínez et al. (2001). The researcher who delivered the workshop was not involved in the data analysis phase.
2. Meeting 1: Two researchers in the team came together to share and discuss their analysis. Agreement was reached on what constituted a metaphor. As many types of metaphors existed in the transcripts, it was agreed that the next round of analysis would focus only on metaphors related to design and problem-solving.
3. The data were independently coded once again with a focus on metaphors relating to design and problem-solving.
4. Meeting 2: The two researchers met and agreed on the coded data. The metaphors were grouped into a series of general metaphors – for example; Design is a Journey.
5. The frequency of comments for each metaphor was examined for both the pre and post workshop focus groups.

Some examples of different metaphors that were extracted from the data are shown in Table 1 below where it can be seen how the researchers grouped statements from the practicing teachers into metaphors such as; Design is a Journey, Design is Seeing, Design is a Mine, Design is Construction, and so on.

Once the metaphors relating to Design and Problem-Solving were agreed upon by both researchers for the pre and post focus groups, the frequency of each metaphor was examined for both phases. Table 2 provides a breakdown of these frequencies, however, it should be noted that this was a small-scale study and the frequencies provided here give a broad overview of the types employed.

Findings

Primary metaphors drawn on in the pre-workshop discussion

In the pre-workshop discussion the teachers were asked what their understanding of problem-solving was and how they approached it in their teaching. While many different metaphors were employed by the teachers, the most dominant metaphor to emerge in the teachers' responses was that of a journey with 17 contributions to the discussion drawing on descriptions that related to a journey or pathway. For that reason, the pre-workshop findings will focus on this dominant metaphor. These statements appeared to represent problem-solving as a linear process that students were required to follow with

Table 1 Extracts from transcripts for design and problem-solving metaphors agreed by the dual-analysis of the researchers

Design is a journey 1. Figure out the path how to go about that 2. Going through a series of stages 3. Going through different possible solutions 4. Analysing that at the end 5. So looking back to see have they actually solved the problem 6. Path are you going to take 7. They can go from there 8. Rather than jumping straight in 9. They would follow the line	*Design is seeing* 1. Get them to look at the world around them 2. He just had a fantastic brain in terms of problem-solving and how he looked at stuff… 3. He already saw it 4. He could already see the motion… 5. To be able to look at something 6. Critically look at something 7. They physically see it in front them
Design is a mine 1. Try and draw stuff out of them 2. So just trying to tap into their spatial ability first of all 3. Tapping back into Science 4. It's amazing what you can tease out of kids 5. Try and tease the information out 6. We would try to tease it out… 7. You have to tap in intrinsically into them	*Design is construction* 1. Giving them a tiny bit of scaffolding first of all 2. Lot more hands on as well. 3. To push the idea of freehand sketching 4. Like a blank canvas sort of thing 5. They do try and push and try and centre it on the person

Table 2 Frequency of metaphors relating to design and problem-solving during the pre and post PD focus groups

Metaphor	Pre #	Post #
Journey	17	4
Seeing	7	2
Mine	7	
Process	2	1
Time	1	13
Partitioning	4	4
Construction	5	2
Discovery	5	3
Game	4	
Boundary	3	4
Struggle	5	6
Growth	3	
Investing	2	
Emancipation		1
Chance		1
Orientation		2
	Total = 65	Total = 43

references to 'figuring out a pathway' or 'going through a series of stages', as the following examples highlight;

> In terms of the classroom it's what they [the students] are trying to figure out and try to get the solution. So trying to figure out the path and how to go about that. (T4)

> I'd say just going through a series of stages so from the initial problem, analysing that, breaking that down and then going through different possible solutions and looking at the world around them and then hopefully coming up with some sort of solution and then analysing that at the end. (T1)

Further evidence of the journey metaphors also surfaced in the teachers' talk when they discussed the challenges that were frequently experienced by them and their students during this problem-solving process. During this discussion the teachers emphasised the importance of their input and support in this process in order to avoid students getting 'lost' or 'bogged down' in the journey. Teachers' comments suggest that they believed that proper support and guidance would help students overcome these obstacles, thus enabling them to 'fly it a lot quicker', as the following interview excerpts indicate;

> Some kids will just get so lost at the start that they will not even know what to do.. and then you'll have others who will design something that is just impossible… and then they're disappointed when you tell them that they can't make that. (T1)

> When I started teaching them I was naïve enough to say to them 'go on and make that'… and it would end up being a ball of a mess… so you would go back and give them 3 simple steps and they would follow the line and you would have the same project like. (T4)

> Because a lot of kids struggle with the whole aspect of design… you know a brief hits them and they are looking and the words are kind of half camouflaged behind the scenes and if it was broken down a lot better they would probably fly it a lot quicker.. because there is a lot of guys and girls with a lot of talent there and sometimes they just get bogged down with that kind of terminology. (T3)

In line with the metaphor of the journey, which would suggest that there is a defined end-point to the problem-solving process, the teachers' comments suggested that their goal was to get them 'across the line', suggesting that perhaps their focus was on getting the students to complete an artefact as opposed to benefiting from the problem-solving process. For example, in the following excerpt the teacher expresses a concern about having to 'spoon feed' students but feels it is necessary to get an artefact made;

> I hate to say it these days but … .the amount of spoon-feeding.. it has to be done to get them across the line… I mean compared to when I was in school and I remember my Engineering teacher and we had to get stuff done and stuff made. (T3)

A less common metaphorical representation of the design process related to construction and building. Continuing the theme of 'spoon feeding' by teacher 3 above, in the first quote below, the teacher claims that they use 'a tiny bit of scaffolding' to avoid spoon feeding the students. Similarly in the second excerpt below, the teacher emphasises the importance of 'breaking down' a design brief rather than 'jumping straight in';

> I suppose [I use] a small bit of doodling first just to try and draw stuff [ideas] out of them and then when that happens you can actually start posing questions to them and they can start answering it and giving them a tiny bit of scaffolding first of all but not feeding them the full solution or anything like that… because it's amazing what you can tease out of kids [students] as young as even 11, 12, 13 that come in like. (T3)

> Well I find with any of those types of problems.. brain-storming, working out like… breaking down the words and breaking down the brief.. to things like that they can

actually relate to and know already and they can go from there. Rather than jumping straight in and Googling words. (T1)

In addition to the metaphors related to construction, the above excerpts also indicate that the teachers saw the solution to the problem as being within the student. Phrases such as 'drawing stuff out' and 'teasing' solutions from the students indicate that the solutions were innately held within the students and their roles were to help them express them rather than seeing the solutions as something that is developed through experimentation, investigation and iteration. This may reflect the way in which problem-solving is perceived within the subject or the teacher's view of the child as a learner. Regardless of these interpretations, the most significant issue to emerge from this pre-workshop discussion was the emphasis on design problem-solving as a somewhat linear journey towards a clear outcome of a completed artefact.

Post workshop

Following the workshop the participating teachers participated in a second group discussion where they were again asked their views on what problem-solving was, particularly in light of the content of the workshop. The analysis of the teachers' contributions to this discussion found that there was quite a difference in the type and frequency of metaphors drawn on. The most notable issue to emerge from the analysis was the significantly lower amount of metaphors related to journey. Whereas the pre-workshop discussion had 17 references, the post-workshop discussion contained only 4. The most dominant metaphor drawn on in the discussion related to time (pace and speed). As with the previous section, this section will therefore focus on this dominant metaphor of time. In the two excerpts below, for example, the teachers draw on the concept of speed using terms such as 'quick to jump', 'too quick', 'slow process' and 'putting the brakes on', to critique their traditional approaches to teaching problem-solving;

Well, anytime I ever did problem-solving I was always too quick to jump and try and help… as a teacher I was always very much like 'they are struggling… I better get in there quick'… whereas after today, I'm thinking I need to be more relaxed and let them struggle a small bit…. And just because they are struggling doesn't necessarily mean it's a bad thing…. They might come up with better ideas than I have ever suggested ... that's definitely a positive out of today. (T4)

Yeah, I would always have thought, or been a bit too quick. I wouldn't have seen it as such, as a slow process where they take a lot of time to think in between and reflect and go back ... [yeah, yeah … mutual agreement from other participants] … or having more discussion. I would nearly have been teaching those ten lessons in 45 minutes… [yeah yeah … mutual agreement]….or at least thinking I was, but I wasn't, so the time that you need to allow for the ideas to develop, that is something that I am interested to see. (T1)

Yeah, putting the brakes on a small bit… that will be interesting to see. (T2)

Recognition of the fast pace in which they approached problem-solving with their students also highlighted to the teachers the missed opportunities of 'slowing' the process down. For example Teacher 3 acknowledged that with more time student enjoyment would increase and stress would conversely decrease. Similarly, Teacher 1, recognised the educational value of working at a slower pace and acknowledged that there was too much of a focus on getting artefacts made;

> I definitely do think that the timeframe needs to be broadened in Engineering, to have the scope and freedom to actually enjoy doing it. At the end of the day, these kids [pupils] should actually be learning through enjoyment and not through stress. We talk about well-being all the time. (T3)

> Yeah, because we're really, we can't wait to get making … this [the workshop] is taking it at a slower pace, but the end result is probably going to be an awful lot better (T1)

In comparing the dominant metaphors drawn on by the teachers in the pre and post workshop discussions it is evident that there is less of an emphasis on journey and greater awareness of reference to time and the pacing of teaching in the second discussion. The next section aims to discuss these findings and examine their implications for design education.

Discussion

As the analysis of the pre-workshop discussion found, the teachers drew heavily on journey metaphors to describe the problem-solving process and there was a strong emphasis on ensuring students completed the design and manufacture of their projects in the allotted time given. It is worth considering the potential origins of such metaphors used to describe problem-solving. For example, have such metaphorical conceptions of problem-solving been shaped by the curricular demands of the subject, where students are required to solve a problem and design and make an artefact within a specific time period? Therefore, the metaphor of a journey or race may be used as they best represent the perceived pressures the teachers face in ensuring all students complete their project work on time. On the other hand, adoption of such a metaphor may be a result of teachers parroting commonly used discourses about learning as a journey. As a result, this metaphorical conceptualisation could result in teachers paying greater attention to the completion of the artefact, i.e., 'getting over the line' and 'finishing the journey' rather than the educational process of achieving the outcome. The pressures of the examination system in Irish post-primary schools is undoubtedly a factor in the use of such a metaphor. Several commentators and research studies have noted the 'backwash' effect of the examinations system on the nature of pedagogy used in Irish post-primary classrooms (Lynch et al., 2013; NCCA, 2007) and it is easy to see how such demands can influence how teachers (and students) talk about learning and project work in schools which can determine the metaphors they adopt to describe it.

Looking specifically at Technology education in Irish post-primary schools, where the manufacture of an artefact takes precedence over the process of problem-solving, it is perhaps understandable that this metaphor of journey or race is common. That is, the teachers feel the need to get the project completed in the limited time afforded to them. This suggests that how design is embedded within the subject, and the demands of the assessment, may make some metaphors more suitable to describe problem-solving, and as these adopted metaphors become embedded in teachers' discourses, they cement such conceptualisations.

As was evident in the findings, the dominant metaphor drawn on in the post-workshop discussion related to time, speed and pace. This shift from spatially-based metaphors to more temporal-based metaphors could be interpreted as indicating a success in changing the teachers' conceptualisation of the problem-solving process. However, it could alternatively be argued that the workshop, while impressing on the teachers the importance of allowing greater time for the investigatory process, has not challenged the dominant journey metaphor that was originally evident prior to the workshop. That is, while they recognised the need to provide more time for students to investigate and explore solutions, they nonetheless saw the completed artefact as critical. Similar teacher views have been found elsewhere (Nicholl & McLellan, 2008).

But to what extent is seeing problem-solving as a journey or race a problem? There are advantages of seeing the problem-solving process as a linear journey or race. For example, it can maintain a focus on the end result which maintains students' (and teachers') attention on the end goal. It can also help students to see the process as a series of stages that one must undertake to solve the problem. This level of guidance can therefore help the learner achieve their intended goal.

However, on the other hand, representing problem-solving in this metaphorical way has disadvantages. For example, it can reduce a complex, creative and cognitively challenging endeavour to a series of pragmatic steps to achieve success, thus sterilising this messy and multifaceted task to a rather trivial uncomplicated undertaking. In other words, a rigid linear process lacks opportunities for students to iterate which has been stressed as an important feature of problem-solving (Cross, 2006) and creativity (Cropley, 2001; Sawyer, 2006) where students can think about their thinking (Flavell, 1987). Further still, the emphasis on completing the 'journey' downplays the educational merits of the process as the product or completed artefact (and consequently the teacher) becomes the centre of attention (Calavia et al., 2021).

The absence of other metaphorical ways to represent the problem-solving process in their post-workshop talk suggests that a substantial shift in their conceptions of problem-solving was not evident. However this begs the question: to what extent are other metaphorical conceptualisations of problem-solving possible? Can other metaphors offer greater educational potential and remove the focus from the product to the process of problem-solving? Indeed, can alternative metaphorical representations offer greater educational affordances? Alternative spatially-orientated metaphors could be used for example where teachers may see problem-solving as an exploratory process where one explores 'deeper' into an area. This metaphor of 'depth' could for example place less of an emphasis on completing and more on exploring. Such a metaphorical conceptualisation may prevent the teacher and learner seeing challenges as problematic and instead inevitable, expected and an important part of the process. Getting 'stuck' or 'bogged down', common elements of the journey metaphor for example, see challenges as problematic as the process is not 'plain sailing' or 'smooth'. Recognising such obstacles as inevitable, expected and indeed helpful in the problem-solving process could open up different metaphorical ways of describing such encounters. For example, could such 'roadblocks' be alternatively conceptualised as 'creativity junctures' or 'innovation points' and thus celebrated as opportunities to deepen and extend one's knowledge rather than disruptions to an inevitable journey?

Creating opportunities for teachers to experience such junctures themselves in design, either in pre-service or in-service teacher education, would give them the opportunity to reflect on such events and how they dealt with the cognitive disequilibrium of these critical junctures. Scaffolded questions such as, 'what is the educational opportunity of pausing at this point and exploring the nature of the problem?', 'How did this juncture emerge?'

What do you need to do in order to pass this juncture? What psychological tools are available that might help? This would enable teachers to explore the pedagogical opportunities that these occasions can give rise to if the dominant metaphor of journey is replaced with alternative more expansive conceptualisations. This also raises questions about the extent to which the metaphors that teachers draw on are inherited from their pre-service teacher education and whether teacher educators are, unknowingly, leaning on common metaphors that are unhelpful in conceptualising the nuances and complexities of this process. As with literature on how student teachers' practices are influenced by their past schooling experiences (Lortie, 1975), teacher educators' practices are similarly influenced by their past experiences and a recognition of this is needed amongst teacher educators working within this field. Indeed, one of the teachers reflected on his own student experiences before the workshop. A more explicit awareness of the metaphors employed in the field of Design and Technology is needed by both teacher educators and teachers so that they can critically explore the strengths and limitations of their use, both as conceptual devices to frame the teaching process and the educational process of the student. As part of this process, teachers should be encouraged to explore alternative metaphors to conceptualise their practices and ultimately have a broader repertoire of metaphors to draw from.

This exploratory study also raises questions about the nature of the school curriculum and the extent to which it provides sufficient time for students to deeply explore design problems that is an integral part of the terminal assessment of the subjects in Irish schools. As this study has highlighted, the desire to achieve a good grade in their completed work and the limited time afforded to the students in getting their project work completed, prioritises the completion of the manufactured artefact as opposed to valuing the problem-solving and cognitive endeavour of the exercise. If curricula espouse and value such aspects, time needs to be allocated to enable such skills to develop. Indeed, such a critical exploration of this issue by those involved in curriculum design could challenge the conventional approach to teaching and learning in the Technology and Engineering classroom where design and problem-solving would take centre stage and manufacture of the completed solution may not be required or expected (Barlex & Trebell, 2008).

Before concluding it is worth noting that although this study is small-scale and exploratory in nature, it nonetheless helps to raise questions about the taken-for-granted nature of the way design and problem-solving is spoken about and how this can influence teachers' conceptions. Whilst acknowledging that further research in different settings and jurisdictions needs to be undertaken to advance this area, the study does highlight the value of employing CMT to this aspect of design education and the different perspectives this theoretical perspective can bring to the area which has been an issue for some time (Nicholl & Spendlove, 2016; Renzulli et al., 2003; Stables, 2017; Williams, 2017).

Conclusion

This study has highlighted the dominant metaphors drawn on by teachers in their talk to describe the problem-solving process. By synthesising the theoretical base relating to design problem-solving and CMT together with the findings of the small-scale study, the paper highlights a potential new avenue to unearth the hidden assumptions of teachers that are hard to examine otherwise. Thinking in relation to Technology subjects in post-primary schools in Ireland underwent significant change over 30 years ago marking a shift in rationale from their vocational traditions where manufacturing was central towards a more design based focus. This study would suggest that the metaphors drawn on by teachers to explain what problem-solving is, indicates that the historical traditions of 'making' remain evident in the discourse of the subject and therefore subsequently help frame teachers' conceptualisation of the design process within the subject. To a large extent this study highlights how teachers' conceptualisations of problem-solving (and their associated practices) are mediated by prevailing discourses and the curricular demands of the subject. Further still, these dominant metaphorical conceptualisations evident in teachers' talk are not only influenced by how design is positioned within the subject, but the maintenance of these metaphorical conceptualisations cements this prevailing understanding of problem-solving in a reciprocal manner.

There are a number of implications for both practice and research arising from this study. From a practice perspective, the study highlights the need to provide teachers with opportunities to interrogate these metaphors and explore what influence they have on their practice. As part of this, teachers could explore more diverse metaphorical conceptualizations of the problem-solving process and the implications this could have on how they approach the teaching of design in their subject areas. This is supported by Yee (2017) who argues that there is a value in using metaphors to create a discursive space for teachers and students to interrogate assumptions. Teacher educators working in the area of Design and Technology education should also explore this discursive space to examine the extent to which teacher educators parrot such metaphors without critically questioning them. In addition, this study has also shown how the use of co-reflection as part of teacher professional development provides an opportunity to discuss their practice and learn from the experiences of others.

From the perspective of research, the study highlights the need to explore the origins of such metaphorical conceptions. For example, are they acquired during the teachers' time in school as pupils? Are they developed during their teacher education programmes? or, are they acquired when in their roles as qualified teachers? In addition, further research should also explore the metaphors used in teacher education programmes and examine the extent to which teacher educators may, unknowingly, employ a restrictive discourse when talking about design and problem-solving that limits student teachers' conceptualisation of it. The extent to which metaphorical constructions are evident across the spectrum of STEM subjects could also be examined and whether conceptual metaphors in other STEM disciplines could be employed in the traditional Design and Technology area.

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Declarations

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