MALTA REVIEW OF EDUCATIONAL RESEARCH

Volume 16, No. 1., 5-24
Faculty of Education©, UM, 2022

Crossing Boundaries Revisited: Strategies used by science teachers when teaching outside specialism

Doreen Mizzi
University of Malta
doreen.mizzi@um.edu.mt

Abstract
Science teachers in Malta generally have a degree-level qualification in one science subject. Yet, they have to teach physics, chemistry and biology as part of the science curriculum in the first two years of secondary school. Teaching outside specialism, that is teaching a subject that was not studied at degree level or Advanced level, can be challenging because teachers need to learn new content knowledge and develop strategies to teach an unfamiliar area. A qualitative case study was carried out to investigate how a group of science teachers approach the teaching of chemistry as their non-specialist area. Data were gathered through semi-structured interviews. Building on a preliminary study, published in vol.13 no.1 of the Malta Review of Educational Research (Mizzi, 2019a), this paper focuses on how teachers negotiate subject boundaries in dealing with the challenges that arise when planning and teaching chemistry topics. The outcomes of this study demonstrate that teachers either make use of enabling or coping strategies when teaching chemistry and, at times, shift between these two ends of the continuum. The findings show that the strategies adopted are dependent on the teachers' knowledge base, their teaching experience and on their confidence and willingness to expand their own teaching identity. Moreover, particular strategies enabled them to cross boundaries and feel competent at their non-specialist area.

Keywords: teaching outside one's area of science specialism; strategies for boundary crossing; teacher identity; teaching chemistry by non-specialist teachers

Introduction

In Malta, science is part of the core curriculum at lower secondary schools (ages 11 to 13) and it encompasses the teaching of physics, chemistry and biology. This is similar to most European countries, where science is taught as an

integrated subject in the first two years of secondary school (Eurydice, 2011). When Maltese students proceed to the next phase of secondary school (ages 14 to 16) they study one science subject as part of their core curriculum. In Malta, there are three school sectors, State, Church and Independent schools. All State schools and Independent schools are co-educational, and Church schools are usually single sex. Physics is generally taken up in State schools and in most Boys' Church Schools, whereas in Girls' Church schools, and in Independent schools students opt from biology, chemistry or physics as their compulsory science subject (Eurydice, 2014). Students can also opt to study the other two science subjects in addition to their compulsory science, and chemistry is generally taken as an option subject.

Maltese science teachers generally have a teaching degree specialising in one science area that is either in physics, chemistry or biology, yet they would need to teach all science areas when teaching science at lower secondary school. In this scenario, science teachers will be teaching within their area of specialism that is a subject studied at degree level, as well as outside their area of specialism which refers to the teaching of a subject that was not studied at a degree or Advanced level. Indeed, only around a quarter of the science teachers have a degree qualification in chemistry in Malta and the majority of science teachers are either physics or biology specialists. This can be problematic within the local context, because as Nixon, Luft and Ross (2017) argue, teachers will not have the adequate content knowledge and pedagogical content knowledge (PCK) to teach all three areas effectively. Consequently, they encounter several challenges when teaching outside specialism and would need to resort to various strategies to feel better equipped when teaching new and unfamiliar areas.

Literature Review

Crossing Boundaries: Teaching outside specialism

Teaching outside specialism is a common phenomenon in many countries (see Hobbs & Törner, 2019). Within the local context, science teachers would need to learn new content knowledge to make up for the lack of subject knowledge in areas that were not studied at degree level. They would also need to transform content knowledge into PCK by finding suitable representations, activities, explanations, experiments and demonstrations to teach science to young students. In this scenario science teachers learn to use their adaptive expertise by applying the knowledge from their subject expertise to deal with

new situations. This process of switching from teaching their subject specialism to outside their field of expertise is known as 'crossing boundaries'. Boundaries are defined as the "socio-cultural difference leading to discontinuity in action or interaction" (Akkerman & Bakker, 2011, p. 133). Between boundaries there is sameness and continuity as well as discontinuity. In boundary crossing, teachers will experience continuity when using their pedagogical knowledge and curriculum knowledge from their field of expertise to teach an unfamiliar area. They will also experience challenges or discontinuities because the new practices and perspectives required to teach the new subject do not correspond with their current practice. Several studies have illustrated the challenges encountered when teaching outside specialism (Childs & McNicholl, 2007; Kind, 2009; Hasweh, 1987; Hobbs, 2013a; Sanders, Borko & Lockard, 1993). Such challenges have been reported even within the local context in a previous article (Mizzi, 2019a). Teachers exhibit difficulties in finding and selecting appropriate activities and in formulating a lesson plan. Further challenges arise whilst teaching, such as giving limited explanations, perpetuating inaccurate knowledge, being unable to answer students' questions and failing to recognise students' misconceptions. Teachers also tend to avoid practical work or have difficulties in preparing, conducting and explaining particular experiments. To overcome these challenges and cross boundaries teachers resort to using various strategies or mechanisms. Akkerman and Bakker (2011) argue that in a boundary crossing event teachers would learn to negotiate and combine components from different contexts to achieve new understandings to teach an unfamiliar area.

Strategies used to teach unfamiliar areas

In crossing boundaries teachers make use of strategies or 'boundary objects' to teach an unfamiliar area. 'Boundary objects' can be "human or non-human and come in the form of artefacts (tools), discourses (as a common language), or processes that allow the co-ordination of actions" (Hobbs, 2013a, p. 287). Several research studies (Childs & McNicholl, 2007; Harlen & Holroyd, 1997; Hobbs, 2012; 2013a; Kind, 2009; McNicholl, Childs & Burn, 2013; Nixon & Luft, 2015) mention various strategies used to deal with such challenges and issues. These include conducting research from books, Internet and other resources, consulting colleagues who are specialist in the area and repeated teaching experiences. Other teachers resort to using their knowledge from their area of specialism to understand and learn new content or use routine practices to feel safe and secure.

Consulting textbooks, schemes of work and Internet resources when planning lessons is one of the common strategies used. Studies show that non-specialist teachers consult these resources to enhance their content knowledge and to develop teaching ideas or activities (Childs & McNicholl, 2007; Kind 2009; McNicholl et al. 2013). It has also been found that teachers consult fewer resources to prepare lessons within their subject specialism compared to teaching outside specialism. Within specialism they look up resources to gauge the students' level of knowledge rather than to revise the subject content (Kind, 2009).

Seeking advice from colleagues is also another important and popular strategy for boundary crossing. Non-specialist teachers often seek support from subject specialists to learn the missing content knowledge and gain valuable teaching strategies outside their area of expertise (Childs & McNicholl, 2007; Kind, 2009). Hence the development of PCK, as McNicholl and Childs (2010) argue, would be "the product of a social process" since it is "shared, distributed and held across people, material artefacts and social settings" (p. 49). In some cases, experienced technicians also provide essential support to teachers to familiarise themselves with school science practical work (Helliar & Harrison, 2011; McNicholl et al., 2013). Indeed, as McNicholl et al. (2013) contend school subject departments are key places that can support and enhance teacher learning. Various interactions occur between teachers in team rooms or in places where teachers spend their time when not teaching. Within this community teachers feel safe to ask their colleagues for assistance. The knowledge, expertise and resources disseminated amongst colleagues not only support teachers to build their content knowledge and PCK, but also helps them to gain confidence and competence to teach an unfamiliar subject (Hobbs 2013a).

Repeated experience and the outcomes of successful lessons can increase confidence in teaching a subject area (Hobbs, 2013a). Teachers gain more knowledge about students' difficulties, questions and misconceptions when they teach the same topics year after year. These experiences enable them to develop curriculum knowledge, links and connections between and across different topics (McNicholl et al., 2013). As a result, teachers develop a repertoire of 'teacher pedagogical constructs' (Hashweh, 2005, p. 274) that helps them to improve their PCK and gain further knowledge and confidence when teaching unfamiliar topics.

Teachers also tend to draw on ideas from their area of science specialism to understand the new content. Nixon and Luft (2015) explain how teachers with a biology degree drew on ideas from biology when teaching chemical concepts. In their study teachers used the process of osmosis and diffusion to explain the concept of chemical equilibrium. They also used their knowledge of crosscutting concepts across the science areas to connect topics and support their limited knowledge in chemistry.

On the other hand, other teachers use coping strategies to hide their uncertainties and fear of being regarded as unknowledgeable teachers when teaching their non-specialist area. In their research with primary teachers who are non-science specialists, Harlen and Holroyd (1997) found that teachers were prescriptive and relied on worksheets to keep students busy and on task. Teachers also tended to talk for most of the lesson to minimise students' talk and interaction to avoid awkward questions. Thus, lessons became very traditional, and teacher centred. There was very little attempt to include practical work or simple experiments because teachers feared they could not give an adequate explanation to their students if the experiment went wrong. It was also noted that teachers focused in more depth on topics they felt more confident in but skimmed through topics in which they lacked confidence. Such findings suggest that when teaching outside specialism teachers tend to stick to routine and traditional practices to hide their weaknesses and insecurities.

Crossing boundaries and teacher identity

When teaching outside specialism teachers are often concerned about their limited content knowledge and their restricted repertoire of teaching strategies, practical applications and curricular knowledge. This situation affects their self-efficacy as well as their teacher identity. Luehmann (2007) defines the teacher's professional identity as "how one is recognised by self or others as a certain kind of teacher" (p. 827). Teacher identity is a complex construct, and it is constantly changing due to the ongoing experiences and interactions with other people. It is shaped by a variety of factors such as personal histories, actions, events and prior experience (Avraamidou, 2014, 2016), as well by the social context and the interaction with others (Rogers & Scott, 2008). According to Siskin (1994) secondary school teachers tend to describe themselves in terms of subjects that they teach because with time they develop a set of values, norms and viewpoints based on the subject discipline. Furthermore Beeijard, Meijer and Verloop, (2004) argue that in a professional identity there are sub-

identities that need to be balanced to avoid conflict between the different facets. This implies that science teachers may adopt multiple identities when operating in different practices and contexts. They can be more confident to view themselves as subject specialists rather than as generalist science teachers due to the lack of knowledge and teaching strategies in their non-specialist area. The use of support mechanisms or boundary objects can provide an opportunity, as Hobbs (2013a) argues, for re-conceptualisation of practice and renegotiation of one's identity. Hence "boundary objects are central to professional identity development because they improve the likelihood of learning through the boundary crossing event" (Hobbs, 2013b, p. 11). Boundary objects can also help teachers experience boundary permeability when they learn to resolve their difficulties and feel more confident to teach outside specialism (Hobbs, 2013b).

Research area and research question

The phenomenon of teaching outside specialism has not been researched within the local context. As part of my doctorate study, I wanted to investigate how science teachers, who are non-chemistry specialists, approach the teaching of chemistry topics as part of the science curriculum and identify the strategies or boundary objects used to prepare their lessons (Mizzi, 2019b). Indeed, I wanted to address a gap in literature by investigating the type of strategies that enable teachers to cross boundaries and influence their teacher identity as science teachers. The research question that guided this part of the study is:

What type of strategies enable boundary crossing and impact the teachers' knowledge base and identity?

Methodology

This research was developed through a qualitative case study since it gives "an in-depth description and analysis of a bounded system" (Merriam & Tisdell, 2016, p. 37). This paper aims to explore the phenomenon of teaching outside specialism particularly focussing on the strategies that non-specialist teachers use in preparing lessons and in their teaching. As Yin (2009) argues, I was not only interested in 'what' goes on when teaching outside specialism but also wanted to explain 'why' teachers use particular strategies and how the use of these mechanisms affects their knowledge base and teacher identity. This research was carried out with eight non-specialist chemistry teachers who taught science in different secondary schools. These teachers voluntarily opted

to participate in a year-long ongoing professional development (PD) programme to improve the teaching of chemistry. The teachers' experiences and views of this professional development programme are reported elsewhere (Mizzi, 2021). Over the year, I was also meeting teachers to conduct semi-structured interviews to elicit the challenges encountered when teaching chemistry topics and the strategies used to overcome their difficulties. Four interviews were held with each teacher during the scholastic year and a fifth interview took place a year after the PD programme. These interviews led to in-depth conversations and provided an opportunity to understand how the non-specialist teachers construct, interpret and give meaning to their experiences. Semi-structured interviews were the methodological tools selected to capture the participants' experiences, thoughts and behaviours. Generalistions cannot be made since the sample is small, however the teachers' experiences and narratives provide a rich data source that sheds light onto the way teachers negotiate subject boundaries.

Table I shows the profile of the teachers participating in the study. Pseudonyms were used to protect the teachers' identities. Table I also includes whether teachers viewed themselves as generalist or subject specialists. Subject specialists claimed that they felt weaker at teaching chemistry because they did not study the subject as young students or because they had poor experiences when learning chemistry at secondary and post-secondary school. Generalist teachers felt that they had a good background in chemistry and exhibited a passion for teaching all areas of science.

Table I: Profile of the participant teachers

Teachers	Area of specialism	Background in chemistry	Teaching experience	Generalist/ Specialist
Sarah (T1)	biology	Advanced Level	less than 5 years	generalist
Karen (T2)	physics	Intermediate Level	less than 5 years	generalist
Amy (T3)	biology	Advanced Level	less than 5 years	specialist
Daniela (T4)	biology	Advanced Level	more than 10 years	specialist
Laura (T5)	biology	Intermediate Level	5 years	specialist
Christine (T6)	Personal and social development	never studied chemistry	between 5 and 10 years	specialist

Maria (T7)	physics	never studied chemistry	less than 5 years	specialist
Robert (T8)	physics	never studied chemistry	less than 5 years	specialist

All the data from the interviews were transcribed, then coded and arranged into categories and themes. Thematic analysis was used to identify and report patterns within the data (Braun & Clarke, 2006). One of the themes that emerged from the data was 'strategies.' This paper aims to report the data from this theme thereby answering the research question presented.

Findings and Discussion

The purpose of this paper is to outline the strategies or boundary objects that teachers use to bridge the social and contextual worlds between different fields or subjects (Akkerman & Bakker, 2011). These strategies have been classified into two sets namely 'coping mechanisms' and 'enabling mechanisms'.

1. **'coping mechanisms**' include implementing the syllabus through a modular approach, following prescribed material, drawing on one's current knowledge from one's subject specialism and using traditional methods of teaching.

2. '**enabling mechanisms'** include conducting research, seeking support from colleagues and repeated teaching experience.

The teachers' narratives have shown that 'coping mechanisms' are generally used to survive in awkward situations and to temporarily solve the challenges and issues presented. On the other hand, 'enabling mechanisms' allowed teachers to develop their content knowledge, PCK and increase confidence in teaching their non-specialist area. It was the latter type of mechanisms that enabled teachers to cross boundaries, expand their knowledge base and gain more confidence in teaching chemistry.

Coping mechanisms

Coping mechanisms were generally used when teachers felt overwhelmed with teaching an unfamiliar area. One way of avoiding the teaching of one's

non-specialist area is to use a modular approach to teaching science. In this scenario there would be more than one teacher teaching science and each teacher would teach topics pertaining to his/her area of specialism. Such a method was used at Robert's (T8) school a year prior to the conduction of this study. Although this system had its advantages as the teachers felt more confident teaching their subject specialism, Robert (T8) and his colleagues opted out of this system because they presented a fragmented view of science through the modular approach. The following year, that is the year when this study was conducted, Robert (T8) had to teach all areas of science even though he perceived himself as a physics specialist. Indeed, he admitted that he faced considerable challenges when teaching chemistry, a subject he had never studied during his secondary school days.

Another coping mechanism that was generally used by the non-specialist teachers was to follow rigorously what was prescribed in the curriculum or textbooks, as has been found by Kind (2009) and Hashweh (1987). In the current study teachers did not attempt to conduct risky activities due to their limited knowledge base. Maria (T 7), who also never studied chemistry in her secondary school years, felt insecure and admitted that she did not dare *"venture outside the curriculum."* For the topic of chemical changes, she resorted to use a set of experiments suggested by her colleague who is a specialist chemistry teacher where she explained that:

> *I spoke to a friend of mine who has a chemistry background. She indicated three experiments that are a bit 'wow' for students… and I stick to those. I put the chemicals on the bench... I use a double lesson for just three reactions. I get each group next to me on the bench and I discuss with each group. 'What is happening? What do think?'… I do the test for oxygen and hydrogen. Usually out of a double lesson I am then left with twenty minutes in which I tell them to do a write-up. But I stick to those!*

Laura (T5) and her colleagues developed a pack of notes for Year 8 students. She felt more secure when all the teachers were following the same sequence of lessons with a similar structure because as she explained: "*I am covering everything that I have to do, the amount of detail is neither too little nor not much… I am moving on the same lines as other teachers."* In both cases, following prescribed material or common practices such as laboratory work or a set of notes, provided a sense of continuity and ensured consistency within a boundary that was familiar to these teachers. Such strategies could help teachers feel more

secure by restricting their uncertainties, yet it limited their learning and expansion of knowledge in crossing a boundary.

Teachers tend to use knowledge from their subject specialism to understand and explain chemistry concepts. For instance, the topic of 'matter and kinetic theory' is a common topic in physics and chemistry. The physics specialists like Robert (T8) and Maria (T7) could retrieve their knowledge from their subject specialism and use it to teach the topic of 'understanding matter', without the need of conducting further research during lesson preparation. Robert (T8) felt more comfortable to teach such a topic because as he explained *"you try to make sense of things basing on what you know, like I will be trying to understand some chemistry topics by using ideas from physics."* Nixon and Luft (2015) mentioned a similar strategy where biology teachers used real world examples and their knowledge of biology to explain chemistry concepts. Generally, by drawing on one's knowledge and applying it to new areas, one would expand one's understanding and construct new knowledge. However, in the current study since 'kinetic theory' is a common topic in both disciplines, these two physics specialists drew on their knowledge from their subject specialism to teach this unit. Such a circumstance did not enable teachers to cross a boundary because they used their background knowledge to teach a similar area to their subject specialism.

When teachers lack confidence to teach an unfamiliar area, they tend to resort to traditional methods of teaching because they believe that this approach would give them greater control in their lesson (Harlen & Holroyd, 1997). During one of the interviews Robert (T8) mentioned that he uses different approaches when teaching within and outside specialism. He frequently used an inquiry-based learning approach when teaching physics, but he admitted that he delivered a different type of lesson in chemistry where he intentionally would restrict the students' input. Robert (T8) confessed that the lesson plan would be designed in such a way that it would *"be full of activities"*, but after conducting these activities he would *"immediately switch on to something else"* so that he does not *"give time to students to ask questions."* Although in principle this went against his philosophy of teaching and learning, he resorted to this approach to avoid revealing his insecurities about his lack of content knowledge to his students. Indeed, he acknowledged that he purposely changed the sequence of activities to restrict the students' questions.

> *First, I teach the topic and then I do the experiment at the end of the lesson. After the experiment, I would have answered all the questions from*

beforehand…. What will happen? The students will ask fewer questions. If you were to use the experiments as an introduction to the lesson, students would ask many questions and once one student starts with a question they start building up… so I change the lesson plan and when I am not sure about something I leave it till the end of the lesson such that most of the questions would have been tackled in the topic and there won't be any questions during the experiment.

On the other hand, when he felt confident and knowledgeable in the area, he would start his lesson with an experiment to spark students' inquisitiveness because he was not afraid to answer the questions related to the topic.

When I am confident with the topic then I start with an experiment but if I am less knowledgeable, I leave the experiment to the end of the lesson. If I start with an experiment, it will trigger the students' curiosity and they will start asking questions…. This will have a ripple effect on the whole class. Students start pooling questions and the teacher is under test at that time.

Such narrative shows that traditional teaching methods are purposely used to narrow down classroom discourse and gain more classroom control. This episode is similar to Harlen and Holroyd's study (1997) where teachers emphasise expository teaching and minimise questions and discussions. Robert (T8) identified an area of 'discontinuity' between teaching within and outside his subject specialism. Although he was a firm believer of inquiry-based practices, he was not capable of using these ideals when teaching chemistry. As he explained, by constraining students' conversations and curiosity "*the students would already have an idea of what's about to happen. This decreases some of the students' motivation. Experiments are done to prove what was said rather than to stimulate the students' thinking.*"

These coping strategies were more frequently mentioned by the early career teachers who did not study chemistry at secondary school. These coping mechanisms were used as fix-it strategies and teachers could solve the situation only temporarily. These strategies did not enable teachers to gain new knowledge to expand their knowledge base. Through the use of coping mechanisms teachers could hide their insecurities and appear to be in control of the situation. Moreover, the use of coping mechanisms did not enable teachers to cross a boundary because they remained on the side of the boundary that was familiar to them.

Enabling mechanisms

Teachers find many opportunities for learning to teach their non-specialist area by making use of enabling mechanisms or what Hobbs (2013a; 2013b) describes as 'boundary objects' that act as a bridge between the known social world of their subject specialism and the unknown world of their non-specialist area. Given support, non-specialist teachers are able to 'cross the boundary' through a process of active transformation and a reconceptualisation of their teacher identity (Akkerman & Bakker, 2011). The participant teachers made use of the following enabling mechanisms (1) carrying out research using books and the Internet, (2) asking support from colleagues, and (3) repeated teaching experiences which enabled them to develop new knowledge and skills and allowed boundary permeability between their subject specialism and their non-specialist area.

Conducting research from books or the Internet or going through the list of suggested activities in the local science syllabus was the most common strategy mentioned by all teachers. This boundary object was also one of the main supporting strategies described by Childs and McNicholl (2007) and Kind (2009). In this study teachers recognised the need to conduct research because they felt less knowledgeable in chemistry and wanted to address their weaknesses or gaps in subject knowledge. Maria (T7) claimed that she went *"a lot online and read books"* to upgrade her background knowledge. Laura (T5) mentioned that she would "*research a bit more*" than if she were teaching her subject specialism because she "*wanted to be sure to give them the right information and explain things in the right way so the students wouldn't have misconceptions.*" Robert (T8) acknowledged that he needed to *"prepare further in a chemistry lesson"* because he also needed to prepare *"for what the students may ask."* Daniela (T4) also spent considerable time reading various books and using the Internet to ensure that she was knowledgeable enough when teaching chemistry. She stated, "*I read a lot because I do not know enough. I always want to know lots about the topic, and I spend quite some time looking up information.*" Similarly, Sarah (T1) consulted resources and used visual resources to facilitate her understanding of conducting particular experiments. She stated, "*I look up videos in chemistry so that I will be certain about what I need to do in experiments…. and how to answer students' questions.*" On the other hand, Karen (T2) used both books and the Internet to expand her PCK by finding interesting inquiry-based activities for her students.

During the planning stage Amy (T3) and Daniela (T4) also thought of *"worst case scenarios"* or anything *"that could go wrong in the lesson."* They also tried to *"think of all eventualities"* that might crop up in a lesson. Daniela (T4) included extra notes in her lesson plans to ensure that she was well-prepared. These teachers invested their time looking up and reading information not only to upgrade their content knowledge, but especially to improve and overcome the limitations in their PCK. Conducting research enabled teachers to overcome their insecurities and feel more knowledgeable thus being able to 'cross the boundary' because they felt more prepared and competent to teach chemistry topics.

Most of the participant teachers also asked for help from colleagues who are specialist in the area. Support from colleagues assists teachers to gain confidence and be able to 'cross the boundary'. The participant teachers had a good relationship with their school colleagues and spoke highly of them. They felt that they could easily and openly discuss their difficulties without feeling embarrassed about their lack of knowledge or as being perceived as less 'knowledgeable teachers.' Laura (T4), Amy (T3), Robert (T8), Maria (T7) and Christine (T6) mentioned that they often discuss their difficulties with their colleagues and ask them to suggest activities for their lessons particularly in preparing and conducting chemistry experiments. Amy (T3) often asks the senior teacher to suggest examples of experiments. They generally conduct experiments prior to the lesson so that Amy (T3) can revise the chemistry content and feel more prepared and confident for the lesson. She said that:

> *Every time I do experiments, I practice… then I do feel better after…. We try the experiment beforehand. First of all, it's fun trying out experiments together. Every time I try it, I feel better. I feel like I know exactly what is going to happen because I have done it so I can see myself doing it and I feel better doing it.*

Christine (T6) works very closely with her colleague who is a chemistry specialist. Before her lessons, Christine (T6) asks her colleague about "*possible questions that the students can ask."* After the lesson she often checks with her colleague that she has given the correct responses to the students' questions. Christine (T6) explained that:

> *Before the lesson if I find any difficulties, I will talk to my colleague. I try to clear the difficulties from before in case students ask questions. There will be high ability students who ask questions and I get annoyed if I can't*

answer. But I got stuck at times, so I tell the students that I will let them know in the next lesson… and then I go and talk to the chemistry teacher.

Non-specialist teachers often seek support from the subject specialist to check their understanding and construct accurate explanations. Consulting colleagues is a quicker and more effective way of getting information from more knowledgeable others (Eraut, 2007) because as Childs and McNicholl (2007) argue teachers do not need to spend time going through textbooks or other resources.

Other research studies also indicate that consulting colleagues who are subject specialists is a common strategy among non-specialist teachers (Childs & McNicholl, 2007; Hobbs, 2013a; Kind 2009, McNicholl et al., 2013). Laboratory technicians can also provide the necessary support in case of difficulties. Robert (T8) discusses his queries with the laboratory technician before doing an experiment. Similar to Amy (T3), Robert (T8) conducts trial runs with the assistance of the technician and discusses what could go wrong in the experiment:

I ask the technician before I do a demonstration experiment so that I am sure of what I am doing. I ask about how I can vary the experiment by adding a bit more or less from particular chemicals…. You need to know what can go wrong in an experiment.

Christine (T6) also mentioned that she likes to "*try out the experiments [she is] not sure about, so [she would be] more confident … in front of the students.*" She discusses experimental results with the technician during the trial experiments and explained that:

…if there is a result that I am not so happy with, I will ask the lab technician whether I am conducting the experiment correctly. If she does the experiment and obtains similar results, we try to find out what happened. If she does the experiment and it works, then I am doing something wrong. At times I say better try out this experiment beforehand to make sure that it works well.

Laboratory technicians are an important source of expertise to support non-specialist teachers in conducting practical work (Helliar & Harrison, 2011; McNicholl et al., 2013). Both Robert (T8) and Christine (T6) consulted with and

learned from laboratory technicians whenever they had gaps in chemistry knowledge.

Non-specialist teachers often draw on and learn from their work colleagues when they discuss and share knowledge and ideas about classroom practice. During these interactions PCK is enacted in context and "created in practice" (McNicholl et al., 2013, p. 157). Similar to other studies (Kind, 2009; Hobbs, 2013a), the participant teachers acknowledged that they gained confidence and competence in teaching chemistry after collaborating with colleagues. Collegial support led to the development of what Hobbs (2012) describes as "a more positive identity in relation to the subject" (p. 28). As a result, teachers felt reassured and more knowledgeable in what they were doing, thus increasing their motivation and confidence in teaching chemistry topics.

Teachers become more familiar teaching particular topics with repeated teaching experience. The boundaries between different subjects can start to fade away through repeated teaching experience, that is the boundaries become permeable (Whannell & Hobbs, 2018). When the participant teachers were interviewed a year after the PD programme, they remarked that they had gained more confidence in chemistry with repeated teaching experience. For instance, Daniela (T4) mentioned that:

> *I don't have to test activities over again. I don't need to research so much more about certain concepts, because it is the second time, so I had learnt certain things. When I reflect on what worked and what did not work, I would know more from before what terms and questions I need to use.*

On similar lines, Laura (T5) claimed that a year after the PD programme:

> *There were fewer incidents, fewer issues. This year it was good. As time is passing it is becoming easier, I think. You already know what students' misconceptions are; you already know how to handle them. I think the more time passes, the more experienced you become…. when it comes to problems you know how to go about them, or how to present things which are more interesting.*

Teachers became more familiar with common students' difficulties and types of questions asked. Karen (T2) felt more prepared to answer and anticipate students' questions and diagnose their misconceptions. When I met the teachers a year after the PD programme, I found that they gained more

reassurance in their work, exhibited less anxiety and increased their self-efficacy. Repeated teaching experience enabled them to 'cross the boundary' between different subject areas.

These research findings show that teachers made use of the various strategies. Some of these strategies assisted them to address the encountered difficulties temporarily and were grouped as coping strategies. These included: (1) implementing the syllabus through a modular approach; (2) following prescribed material; (3) drawing on knowledge from area of expertise; and (4) traditional methods of teaching. Teachers also made use of other strategies that enabled them to learn at the boundary and expand their knowledge base. These strategies were coined as enabling mechanisms and include: (i) conducting research; (ii) seeking support from colleagues; and (iii) repeated teaching experience. These strategies are very similar to those presented in the literature, yet the teachers' narratives not only illustrate the strategies used but explain why teachers opted to use them. Furthermore, it was when teachers conducted research, sought support from their colleagues and retaught the subject that they increased their competence in teaching outside specialism. Such findings answer the research question because it was the enabling mechanisms that helped teachers to resolve the discontinuities and tensions arising during boundary crossing.

Conclusion and recommendations

Subject boundaries can be "potential learning sources rather than barriers" (Akkermann & Bakker, 2011, p. 137). Learning at the boundary involves teachers exercising their sense of agency, applying their knowledge and adapting to new practices and situations. In such processes teachers learn how to use their adaptive expertise, that is, they learn to apply knowledge effectively to new situations. When teaching outside specialism "teachers find themselves in situations where they must 'do research', learn from colleagues and be adaptable. How a teacher copes in these situations is not just critical to their practice but also for their professional identity" (Hobbs, 2012, p. 26). The findings of this study add on to the theory of boundary objects and have shown that teachers were able to 'cross boundaries' when they used 'enabling mechanisms' because they felt more competent to teach a new area. On the other hand, when teachers did not feel equipped with the necessary knowledge and skills either because of lack of teaching experience or because they did not study chemistry at secondary level, they resorted to use coping mechanisms because they did not feel ready to move out of their comfort zone and adapt to

new situations. They remained on the side of the boundary that was familiar to them and viewed themselves as specialists rather than generalist teachers. The evidence provided by this research suggests that the teachers' knowledge base and teaching experience determine the type of mechanisms employed. This study has shown that all teachers attempted to use enabling mechanisms because they all conducted research prior to their lessons, and they consulted their colleagues in case of difficulties. However, those teachers who did not study chemistry at secondary level and were early career teachers tended to use both mechanisms depending on how confident they felt with the topic being covered. These particular teachers shifted between the two ends of the continuum, because although they invested time in research to learn more about the subject, they also demonstrated limited adaptability and resorted to use coping strategies. They could have struggled more in chemistry due to the lack of repeated teaching experience. On the other hand, Christine (T6) also did not study chemistry as a young student but teaching experience and the continuous support from her colleagues enabled her to learn the subject and find interesting teaching activities for her lessons.

These findings challenge the taken-for-granted assumption that specialist teachers are adequately prepared to teach all areas of science (Nixon et al., 2017). When teaching outside specialism teachers need to learn how to adapt and take on a new identity as science teachers. Although most of the participants identified themselves as subject specialists, they were open to take risks and make the leap to overcome the challenges by using enabling mechanisms. In this context teachers made a conscious decision to move away from being in a less knowledgeable position. Thus, they spent their time in research, in seeking collegial support and in repeated teaching experience. This encouraged a change in their perceptions, motivations, beliefs and dispositions towards teaching a new area, thereby expanding their teacher identity. Indeed, a year after the PD programme, all teachers felt that they had gained more confidence and were less afraid to tackle the chemistry topics.

Identity transformation, that is embracing the role of a generalist teacher despite being trained as a subject specialist, is a very slow process. As DuPlessis (2017) argues, teachers need time to "internalise the expectations of a specific subject, content knowledge and pedagogical content knowledge (p. 22). Identity transformation will also depend on the teachers' level of commitment, classroom experiences and willingness to adapt to teach a new subject. Indeed, the participant teachers were willing to learn and expand their knowledge

base. The use of enabling mechanisms supported the teachers to improve their knowledge base and change their beliefs and attitudes towards chemistry thus bringing about shifts in their teacher identities. The findings of this study have shown that enabling mechanisms are important strategies that enable teachers to address their gap in knowledge and empower them to reconcile the tensions between their multiple identities. However, one would question whether the use of enabling mechanisms would suffice to resolve the tensions existing between the teachers' multiple identities such that science teachers would identify themselves as generalist teachers rather than subject specialists. Continuous interactions and discussions with colleagues having different areas of specialism with the school community together with repeated teaching experience are highly beneficial for teachers to expand their knowledge base and their professional identity. Thus, the formation of community of learners within the schools is indispensable to stimulate teacher learning and growth. Considering that several teachers in Malta are engaged in teaching science at Year 7 and 8, the identity expansion process would also need to be complemented with long-term support. Ongoing professional development can help to increase boundary permeability. However, it needs to be designed in such a way such that teachers take an active role in their learning process and form part of a community of learners. The ongoing support would enable teachers to expand their knowledge base, change their practices and become more confident to teach their non-specialist area, thus enabling the transition from specialist to generalist science teachers.

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, *81*(2), 132-169.

Avraamidou, L. (2014). Tracing a beginning elementary teacher's development of identity for science teaching. *Journal of Teacher Education*, *65*(3), 223-240.

Avraamidou, L. (2016). Studying science teacher identity. In L. Avraamidou (Ed.), *Studying science teacher identity: Theoretical, methodological and empirical explorations* (pp. 1 – 14). Rotterdam, Netherlands: Sense Publishers.

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education*, *20*(2), 107-128.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Childs, A., & McNicholl, J. (2007). Science teachers teaching outside of subject specialism: Challenges, strategies adopted and implications for initial teacher education. *Teacher Development*, *11*(1), 1-20.

Du Plessis, A. E. (2017). *Out-of-field teaching practices: What educational leaders need to know*. Rotterdam: Sense publishers.

Eraut, M. (2007). Learning from other people in the workplace. *Oxford review of education*, *33*(4), 403-422.

Eurydice, (2011). "*Science Education in Europe: National Policies*." *Practices and Research*. http://eacea.ec.europa.eu/education/eurydice/documents/thematic_reports/133EN.pdf

Eurydice, (2014). *Malta: Overview*. Retrieved from https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Malta:Teaching_and_Learning_in_General_Lower_Secondary_Education.

Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International Journal of Science Education*, *19*(1), 93-105.

Hashweh, M. Z. (1987). Effects of subject-matter knowledge in the teaching of Biology and Physics. *Teaching and Teacher Education*, 3(2), 109-120.

Hashweh, M. Z. (2005). Teacher pedagogical constructions: a reconfiguration of pedagogical content knowledge. *Teachers and Teaching*, *11*(3), 273-292.

Helliar, A. T., & Harrison, T. G. (2011). The role of school technicians in promoting science through practical work. *Acta Didactica Napocensia*, *4*, 15-20.

Hobbs, L. (2012). Teaching out-of-field: Factors shaping identities of secondary science and mathematics. *Teaching Science: The Journal of the Australian Science Teachers Association*, *58*(1), 23-31.

Hobbs, L. (2013a). Teaching 'out-of-field' as a boundary-crossing event: Factors shaping teacher identity. *International Journal of Science and Mathematics Education*, *11*(2), 271-297.

Hobbs, L. (2013b). Boundary crossings of out-of-field teachers: Locating learning possibilities amid disruption. In, J. Langan-Fox & C. L. Cooper (Eds.), *Boundary-Spanning in Organizations: Network, Influence, and Conflict* (pp. 7-28). New York: Routledge.

Hobbs, L., & Törner, G. (2019). Teaching Out-of-Field as a Phenomenon and Research Problem. In L. Hobbs & G. Törner (Eds.). *Examining the Phenomenon of "Teaching Out-of-field" (pp. 3-20)*. Singapore: Springer

Kind, V. (2009). A Conflict in Your Head: An exploration of trainee science teachers' subject matter knowledge development and its impact on teacher self-confidence. *International Journal of Science Education*, *31*(11), 1529-1562.

Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education*, *91*(5), 822-839.

McNicholl, J., & Childs, A. (2010). Taking a sociocultural perspective on science teachers' knowledge. In V. Ellis, A. Edwards, & P. Smagorinsky (Eds.), *Cultural-historical perspectives on teacher education and development: Learning teaching* (pp. 45-63). London: Routledge.

McNicholl, J., Childs, A., & Burn, K. (2013). School subject departments as sites for science teachers learning pedagogical content knowledge. *Teacher Development*, *17*(2), 155-175.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco: Jossey-Bass.

Mizzi, D. (2019a). Teaching Science: Challenges Encountered When Teaching an Area outside Science Specialism. *Malta Review of Educational Research* 13 (1): 5–23.

Mizzi, D. (2019b). *Supporting teachers when teaching outside their subject specialism.* (Unpublished Ph.D. thesis), University of Malta.

Mizzi, D. (2021). Supporting science teachers teaching outside specialism: teachers' views of a professional development programme. *European Journal of Teacher Education*, *44*(5), 706-725.

Nixon, R. S., & Luft, J. A. (2015). Teaching Chemistry with a Biology Degree. In J.A. Luft & S.L. Dubios (Eds.), *Newly Hired Teachers of Science*: *A Better Beginning* (pp. 75-85). Rotterdam, Netherlands: Sense Publishers.

Nixon, R.S., Luft, J.A., & Ross, R. J. (2017). Prevalence and Predictors of Out-of-field Teaching in the First Five Years. *Journal of Research in Science Teaching* 54 (9), 1197–1218.

Rodgers, C. R., & Scott, K. H. (2008). The development of the personal self and professional identity in learning to teach. In M. Cochran-Smith, S. Feiman-Nemser, D. J. McIntyre, & K. E. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed., pp. 732–755). New York: Routledge.

Sanders, L. R., Borko, H., & Lockard, J. D. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. *Journal of Research in Science Teaching*, *30*(7), 723-736.

Siskin, L. S. (1994). *Realms of knowledge: Academic departments in secondary schools*. London: Falmer Press.

Whannell, R., & Hobbs, L. (2018). On becoming a science teacher. In G.Woolcott & R. Whannell (Eds.), *Teaching Secondary science: Theory and Practice* (pp. 24 - 44). UK: Cambridge University Press.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage.