MALTA REVIEW OF EDUCATIONAL RESEARCH

Volume 13, No.1., 5-23
Faculty of Education©, UM, 2019

Teaching Science: Challenges Encountered when Teaching an Area Outside Science Specialism

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Abstract
Integrated Science is taught in the initial two years of secondary school in Malta and includes topics from Physics, Chemistry and Biology. Most Science teachers are likely to have a degree level qualification in one Science subject, therefore when teaching Integrated Science they would need to teach topics that they might not have studied beforehand. When teaching outside science specialism teachers will be teaching a subject/s that they did not study at Degree or even at Advanced Level. This can offer considerable challenges. The research study was carried out to explore the main challenges that Science teachers, who are non-Chemistry specialists, encounter when teaching Chemistry topics from the Integrated Science syllabus. Following a qualitative methodological approach, data were gathered mainly through interviews and classroom observations. This paper presents three case studies of participant teachers who narrate their experiences when planning and teaching Chemistry topics and how this affects their self–efficacy and identity as Science teachers. Teachers also describe how they deal with these challenges to improve their practices. Based upon the outcomes of this research recommendations are provided to support teachers in teaching outside an area of their science specialism.

Key words: teaching outside specialism; teaching Integrated Science; non-Chemistry specialist teachers; teacher identity

Introduction

Science in secondary schools is taught using different approaches ranging from integrated approaches to more specialised approaches (Eurydice, 2011).

In Malta, State secondary schools are made up of the middle schools (Year 7 and 8) and the secondary schools (Year 9 to Year 11) (MEE, 2012). In the middle school, students learn Integrated Science as part of the core curriculum. The Integrated Science syllabus includes topics from Physics, Chemistry and Biology. At secondary school, students study one Science subject as part of the compulsory curriculum. In State schools and in most of the Boys' Church Schools students generally study Physics as their compulsory Science (Eurydice, 2014). Students in most of the Girls' Church Schools, in some of the Boys' Church Schools and in Independent Schools choose either Physics or Chemistry or Biology as their compulsory Science subject. At the end of Year 8 students may opt to study one or two Science subjects in addition to their compulsory Science subject. In other words, students at secondary level study a compulsory Science subject. The uptake of the other two Science subjects depends on the students' choice, so that not all the students study the three Sciences at secondary school.

Maltese Science teachers would have generally specialised in one Science area (that is either in Physics, Chemistry or Biology) in their teaching degree and in this paper this will be referred to as their area of Science specialism. During the initial teacher education programme prospective teachers would have studied the other two science subjects at a broad level. When teaching Integrated Science teachers will be teaching both within their area of specialism and outside their Science specialism, which means that these teachers would not have studied the subject at Degree or at Advanced level (Childs & McNicholl, 2007). For instance, a Physics teacher with a B.Ed. (Hons.) degree in Physics teaches within one's area of Science specialism when teaching Physics topics, but teaches outside his/her area of Science specialism when teaching Chemistry and Biology topics which are part of the Integrated Science syllabus. What is more problematic in the local context is that since Physics is the compulsory science in most secondary schools, a large number of Physics teachers may not have studied Chemistry and Biology at secondary level, but they are expected to teach these subjects as part of the Integrated Science curriculum.

Teaching outside one's area of science specialism

The role of the Science teacher is a multifaceted one. Science teachers are required to take on the role of 'subject specialists' when teaching a Science discipline they would have studied at Degree level, as well as a more 'generalist' role when teaching Integrated Science. The major issue and

concern related to teaching outside one's area of Science specialism is that teachers have limited subject matter knowledge (SMK) (Childs & McNicholl, 2007; Kind 2009). They also lack the knowledge required to adapt subject knowledge for teaching, what Shulman (1986) describes as Pedagogical Content Knowledge (PCK). Bennett (1993) claims that adequate knowledge and understanding of the subject is required for teachers to effectively diagnose students' misconceptions, make appropriate curricular choices, plan suitable tasks and present quality explanations and demonstrations. When teachers teach outside their Science specialism they need to learn both the subject content knowledge as well as PCK in order to be able to transform the content into representations, activities, demonstrations and exercises to facilitate students' understanding (Shulman, 1987).

Research carried out with both trainee and experienced teachers (Childs & McNicholl, 2007; Hashweh, 1987; Kind, 2009; Kind & Kind, 2011; Sanders, Borko & Lockard, 1993) has shown that teachers experience various challenges and issues when planning lessons and teaching outside their area of expertise. Kind (2009) suggests that compared to experienced teachers, trainee teachers may encounter bigger challenges when teaching outside specialism.

Drawing on various research studies (Childs & McNicholl, 2007; Hashweh, 1987; Kind, 2009; Kind & Kind, 2011; Millar, 1998; Sanders et al. 1993), the main challenges encountered by teachers occur whilst planning lessons and when teaching a subject due to lack of familiarity of both content and curricular knowledge. Planning lessons outside an area of expertise tends to be time consuming since teachers often have gaps in content knowledge and its understanding (McNicholl, Childs & Burns, 2013). Moreover, lesson planning can entail a very laborious process because teachers experience difficulties in deciding the key concepts in a lesson, in organising the unit and in linking different aspects of content. They are also unsure about how to sequence the content and how long the activities may take (Sanders et al., 1993). All these factors make teaching a non-specialist area more challenging and demanding than teaching within specialism. Furthermore, pedagogies used and classroom interactions tend to be limited due to having a restricted knowledge of potential activities and analogies required to explain particular concepts (Childs & McNicholl, 2007). The lessons become teacher dominated, allowing very little time for student talk (Carlsen, 1993). Teachers also face considerable difficulties in answering students' questions, in devising

practical work and in identifying students' misconceptions (Childs & McNicholl, 2007; Millar 1998).

Kind and Taber (2005) argue that teaching outside one's area of science specialism creates a "professional dilemma" because Science teachers are looked up to for their specialists' skills and yet they are expected to "teach as 'experts' throughout the whole science area" (p. 16). Consequently, teachers become apprehensive and lack confidence when teaching outside specialism. This will affect the way they perceive themselves as Science teachers, that is their teaching identity which can be defined "as being recognised by self or others as a certain kind of teacher" (Luehmann, 2007, p.827). Beijaard, Meijer and Verloop (2004) notes that "identity is an ongoing process of interpretation and re-interpretation of experience" (p. 122). They further argue that identity involves both a person and a context and that within a professional identity there are sub-identities which must be balanced to avoid conflict between the different facets. Teacher identity develops over time and is shaped by a variety of factors such as personal histories, actions, events, previous experiences as science learners, contextual factors, social interactions and participation in discourse and practices as part of a community of practice (Avraamidou, 2014). A teacher's identity is highly influenced by the subject taught (Siskin, 1994) and, as Hobbs (2011) argues, the development of a subject teacher identity is a continuous process of identity construction and negotiation that takes place when teachers interact with and reflect on their personal and professional experience. However, dilemmas in the teacher's sub-identity can be created if the teacher does not feel so competent in teaching a particular subject area.

Research Area

The research presented in this paper was carried out within the Maltese educational context. As a Chemistry Head of Department in a Maltese Church school, I often came across Integrated Science teachers who expressed their concern and anxiety when they came to teach the Chemistry topics in the Integrated Science syllabus. From my conversations with these teachers I realised that although these teachers had expertise in other areas of Science such as Biology and Physics, when it came to Chemistry they were very insecure, lacked confidence and found teaching Chemistry topics quite challenging. As part of my doctoral research I was therefore interested in exploring the challenges faced by Science teachers, who are non-Chemistry specialists when teaching Chemistry topics in the Integrated Science

curriculum. The study also seeks to understand how teachers deal with the challenges when teaching such topics and how they seek to improve their practices. Two of the research questions of this research study include:

- What are the challenges faced by Science teachers who do not have a background in Chemistry when teaching Chemistry topics in the Maltese Integrated Science curriculum?

- How do non-specialist Chemistry teachers cope with the challenges that they face when teaching Chemistry topics in Integrated Science?

This study was carried out with Science teachers who voluntarily opted to participate in a professional development programme for non-specialist Chemistry teachers. This paper will portray the lived experience of three of the teachers participating in the study. The paper presents a narrative of the teachers' journey as they went through the process of planning and teaching Chemistry topics, the challenges they faced and how they tried to improve their practice. Throughout, I wanted the voices of these teachers to be heard as they outlined the various difficulties they encountered and described how teaching a subject they lacked confidence in affected their self-efficacy and their professional identity as Science teachers.

Methodology and data collection methods

This research study adopts a qualitative methodology as a strategy for inquiry since "qualitative research is based on the belief that knowledge is constructed by people in ongoing fashion as they engage in and make meaning of an activity, experience, or phenomenon" (Merriam & Tisdell, 2016, p. 23). A case study approach was chosen to investigate a particular phenomenon within its real-life context (Yin, 2009), in order to gain a deeper understanding of particular experiences from the participants' perspectives in their own contexts and to find out how teachers construct their realities and interpret their experiences when teaching outside specialism. The limitation of this type of methodology is that generalisations cannot be made. Yet, the strength of this approach is that it provides in-depth insights into the issues and challenges that teachers face in teaching Chemistry based topics.

The research was carried out with eight non-specialist Chemistry teachers who were teaching Integrated Science in Church schools. Qualitative research tools were chosen to gain an in-depth perspective of how these

teachers were living their personal and professional story as Science teachers. Multiple research tools were chosen to capture the participants' experiences, actions and behaviours and data were mainly collected in the form of lesson observations, individual semi-structured interviews and focus group interviews.

As a researcher I was aware that ethical issues pervade all stages of the research journey since qualitative research involves the collaboration and participation of research participants when they share their personal experiences of their own situation (Hatch 2002). Cohen, Manion and Morrison (2007) mention a number of ethical issues that need to be taken into consideration when conducting research. Following their suggestions, I first obtained ethical clearance from the University of Malta. Then I gained access and acceptance in the research field by asking permission from gate keepers, that is, from the Secretariat of Catholic Education and from Heads of Schools. I provided the necessary information to participant teachers by explaining what the research study would entail, the data collection methods and the role of participants in the research (Denscombe, 2014). I assured them that participation was voluntary and that they could opt out of the research at any point without giving justification. Besides obtaining informed consent, I also maintained privacy, confidentiality, anonymity, ensured the welfare of the participants and protected their interests. Pseudonyms are used in the write up to protect the participants' identities. I also aimed to gain trust and maintain a good rapport with the participant teachers, thus respecting the relationship between the participants and the researcher.

Thematic analysis was used to analyse the data in order to identify, examine and report patterns of themes within the data (Braun & Clarke, 2006). I followed the guidelines outlined by Braun and Clarke (2006) when conducting thematic analysis. These include: familiarising oneself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and writing the report. In this paper two themes, that is identifying the challenges that Science teachers were facing when teaching outside their area of Science specialism and how teachers cope with these challenges will be discussed by using the data of three teachers, Maria, Robert and Laura (not their real names), taking part in the study.

Introducing the three Science teachers

Maria

Maria never studied Chemistry at secondary and post-secondary level. She initially graduated as an Engineer and worked in industry. Later on she decided to read for a Postgraduate Certificate in Education (PGCE) specialising in Science, and graduated as a Science teacher. She is an early career teacher, teaching Integrated Science to Grade 7 and 8 students in a Girls' Church School. She considers herself to be a Physics specialist due to her strong background in Physics and engineering. However, she does not mind teaching Integrated Science because she is interested in Chemistry and is aware that young students generally become highly engaged and enthusiastic while carrying Chemistry experiments.

Robert

Robert never studied Chemistry and Biology during his secondary and post-secondary education. He furthered his studies in Physics and graduated with a B.Ed. (Hons.) degree in Physics and Science. He teaches Physics to Grade 9 students and Integrated Science to both Year 7 and 8 students in a Boys' Church School. He is also an early career teacher. Robert becomes very apprehensive when teaching Chemistry topics due to his perceived lack of Chemistry content knowledge. He considers himself to be a Physics specialist, though he does not mind teaching Integrated Science since he likes to learn about new areas and draws links between the science domains.

Laura

Laura studied Biology, Chemistry and Physics at secondary level. At post-secondary level she studied Chemistry at Intermediate level. Laura furthered her studies in Biology at tertiary level and graduated with a B.Ed. (Hons.) degree in Biology and Science. She currently teaches Biology in a Boys' Church School. Laura taught Biology for five years and considers herself to be a Biology teacher. Her experience in teaching Integrated Science is relatively new, since she has only been teaching Integrated Science for two years. Laura recognises the need for students to learn all three science subjects and does not mind teaching Integrated Science because she believes that Science should be taught through a holistic approach.

Findings

The findings presented in this research paper are part of a larger study that included more participants and focused on other aspects. In their own voices, the three teachers comment on the challenges they experience when planning and teaching Chemistry topics, their fears and anxieties and how they try to resolve their insecurities and become better Science teachers.

Teachers' experiences when teaching Integrated Science

Maria, Robert and Laura described how they perceived themselves as Science teachers. As they talked to each other, it became evident that they felt more comfortable teaching topics within their area of specialism than topics they were not so familiar with. Their conversations provided a number of insights into their experiences when teaching Integrated Science.

Maria: *I feel more confident and comfortable teaching Physics topics due to my background in Physics and engineering. Physics is my forte! When teaching Physics topics I can easily get through it, I can explain it and I have enthusiasm…. But in Chemistry I get stuck! Chemistry is a subject that I lack and I regret that I did not study it before studying to become an engineer. When teaching Chemistry, I skim through things and I keep it vague … which is a pity because I don't have a background knowledge so it difficult to adapt for the students.*

Robert: *I feel more confident teaching Physics because these are the topics that I am more familiar with. I never studied Chemistry and I feel more limited. I cannot give the same lesson like when I teach Physics. At times I go into class and start wondering: 'Will I manage to succeed today?'*

Laura**:** *My area of specialism is Biology. I feel more comfortable teaching Biology topics because it is easier to do it with the younger students. When it comes to Chemistry….hmmm….I feel very insecure and out of my comfort zone because my knowledge of Chemistry is very weak. Chemistry was not my favourite subject at school… Although I have an Intermediate level in Chemistry, I passed because I studied everything by heart, not because I understood the basics! My foundations aren't good and it will be very difficult for me to feel confident because if you don't have a good basis…It is like a language, if you don't know the alphabet you cannot learn how to spell…That is how I feel about Chemistry!*

As can be seen, these three teachers felt more comfortable and secure when teaching their Science specialism because they felt more knowledgeable in their area of specialism. They identified themselves with their area of specialism and thought of themselves as subject specialists. They felt more competent in their subject specialism, valued this science subject more and wanted their colleagues to view them as experts in their field. Maria, Robert and Laura constructed their personal and professional identity as teachers of Biology or Physics due to what Helms (1998) describes as a strong affiliation with their subject specialism. They derived their professional identity from teaching their subject specialism because teaching their subject area influenced both their actions and attitudes (Siskin, 1994).

As expressed in their personal narratives Maria, Laura and Robert thought of themselves as highly effective teachers of their subject area. However, they had built a different perception of themselves when it came to teaching Chemistry topics. This perception was riddled with feelings of anxiety and insecurity. Overall, they felt out of their comfort zone and not confident to view themselves as 'generalist' Science teachers since they did not feel capable to teach all areas of science. These teachers lacked confidence and felt that they did not have "the necessary knowledge of content, strategies and learners to teach" (Hobbs, 2012, p. 26). Their insecure feelings were mainly developed from their beliefs that they did not have the necessary knowledge to teach Chemistry topics and from their own personal experiences of learning or not learning Chemistry at school.

While Laura had studied Chemistry at Intermediate level she never liked the subject due to her poor school experiences and her perceived gaps in content knowledge. Hobbs (2011) argues that "teachers' socio-historical interactions with their subject equip them with competence and confidence in their teaching" (p. 2).

Both Maria and Robert never studied Chemistry, thus they had a very limited background of Chemistry content knowledge. They were learning Chemistry content whilst teaching, and felt only slightly ahead of their students. This created further uncertainty because they could not foresee how the topics could be developed. As a result, they faced a number of problems during lesson planning.

Preparing lesson plans to teach Chemistry topics

Planning to teach Chemistry topics can turn out to be a demanding task for a non-specialist Chemistry teacher. In the next dialogue Robert, Maria and Laura discuss how they feel when planning Chemistry lessons and the challenges they come across.

Robert : *When preparing to teach Chemistry topics I am not sure about how to develop the lesson and I start asking: 'from where am I going to start? How will I continue, how will I put it all together?' When I am planning Chemistry lessons I feel that I am learning with my students. I have to prepare more because I have to learn Chemistry content. So I am just a bit ahead of my students. In Chemistry it is still a trial and error phase. I am still testing out which activities work best for my students.*

Maria: *When I am planning a lesson I panic because I would have found many resources but I don't know how to use them all…like how much detail should I delve into? I get lost when I can't picture how the lesson will be developed…I take a very long time to prepare a lesson, because I use the Internet, books and do some background reading. Although I prepare a lot I still feel that at times I skim through things because I am weak so I mention them only minimally in the lesson.*

Laura: *At times I have difficulties when doing research. I would not know how to go about 'googling' it… which key words should I use to get good resources? I prefer to discuss it with my colleague, it is easier.*

Robert: *I have the same problem as well… there are experiments that I am not aware of. I have to type specific key words to retrieve what I need … but how will I know that I have found good resources? I never studied Chemistry and cannot rely on my student experiences at school.*

This conversation shows that lesson planning outside one's area of expertise is a very demanding, laborious and time consuming task. As suggested by Child and McNicholl (2007), when teaching unfamiliar areas, teachers first need to learn new subject content knowledge and then they need to learn how to teach this content. Thus when teaching outside specialism, teachers frequently act as learners and they would need to revise or at times even learn new Chemistry concepts prior to teaching. In fact, Maria, Robert and Laura all stated that they conducted extensive research to make up for their

lack of content knowledge. From the teachers' conversations it is evident that the level of SMK was impacting on how they planned their lessons. They had a number of uncertainties with regard to how to develop a lesson, link concepts, find and select appropriate activities and put them in the appropriate order. These difficulties were also observed in a study by Childs and McNicholl (2007) where, like Maria, Robert and Laura, the teachers had difficulties in selecting suitable and effective strategies and resources that promote learning because they lacked the subject content necessary to make informed decisions. Furthermore, Robert and Laura mentioned that they could not conduct an effective Internet research to retrieve resources due to their gaps in content knowledge. These teachers have shown that they lack both the 'knowledge of curriculum organisation' and 'knowledge of resources' which are two of the components of PCK formulated by experienced teachers (Lee & Luft, 2008). From their conversation it was evident that the participant teachers were facing a number of difficulties in planning their Chemistry lessons due to their limited SMK which could not be adequately translated into content specific PCK, thus affecting affected their teaching.

Teaching Chemistry topics

Teachers discussed their experiences when teaching Chemistry lessons. In the next dialogue the three teachers discuss the common challenges encountered when teaching Chemistry topics.

Maria: *When teaching Chemistry topics I cannot go a step further… I can't delve into deeper explanations due to my limited background … To feel safe I don't venture outside the curriculum because with my background I cannot speak about certain things I don't know. I tend to give vague explanations because I feel that I can't elaborate more … and I start doubting … 'Am I making sense? What am I saying?' If I cannot picture it in my head then I am not sure about it…. and that is where I feel weak.*

Robert: *In Chemistry lessons, at times I get stuck explaining theory.*

Laura: *I am very concerned about my explanations … the fact that I am weak in the subject I pay more attention to how I say certain things to make sure I don't pass on any misconceptions.*

Robert: *I don't like it when I give incorrect information to students.*

Maria: *Even me my biggest struggle is that since I don't have a deep knowledge of Chemistry with regards to reactions I stick to this criterion: I never want to mislead my students. I am always afraid of creating misconceptions myself, that is my biggest fear!*

Laura: *When it came to Chemistry experiments, it was not that easy for me because as I have said before my experience of Chemistry at school was not very good. We barely did any experiments. I had Chemistry at Intermediate level but we did not do any experiments. So Chemistry experiments were a bit taboo. I did not know what to expect. I did not know what things mean, so it is more lack of knowledge, lack of experience but when it comes to Biology is different because it is my area.*

Robert: *I did not have a clue which experiments I had to use in lesson plans. Since I don't have a Chemistry background I don't remember the teacher conducting an experiment. Last year I did not do many Chemistry experiments because I don't know the theory behind the experiment …although I had all the equipment in the lab I was not sure where the experiment could lead to… Like what will I be teaching to the students? Will I know how to answer if someone asks a question?*

Maria: *My biggest fright is always one… If you don't know the background in Chemistry, you risk telling your students something wrong and that for me is the worst thing that can happen. Then I will feel really shaky… because students ask good questions, some students really challenge you… If I don't know exactly what is happening in the background, I cannot tell them.*

Robert: *When students ask questions I feel more confident in my subject area, I give more elaborate explanations and I keep going on. But when it is not my area I will be more anxious when students ask questions. It will be different and I start wondering… Where will this question lead to? How will I answer? I hope I am not giving an incorrect answer.*

Laura**:** *In my subject specialism it is easier because if students ask a question, I may have heard it before and I know what to say. But I feel really annoyed in Chemistry. There are many reactions and I did not know what was happening…. Like if there is a precipitate, what is the precipitate? And I feel really annoyed during the lab sessions when students ask 'What is this Miss? Don't you know?'*

Teachers encountered greater difficulties and challenges when teaching outside specialism than when teaching within specialism. These included giving limited and less elaborate explanations, sticking to what is proposed by the syllabus, perpetuating misconceptions, difficulty in tackling students' questions and not being able to explain what happens in practical work. The teachers' descriptions of their realities show that they are highly concerned about their quality of teaching. They admitted that they had difficulties when teaching outside specialism because they had limited or inadequate subject content knowledge and thus found it challenging to teach a subject in which they felt very weak in. The challenges faced by the participant teachers are consistent with research studies tackled in this area (Childs & McNicholl, 2007, Hashweh, 1987; Kind 2009, Millar, 1988; McNicholl et al., 2013, Sanders et al., 1993). Having a good background of the subject is a crucial requirement for effective teaching but this is not enough (Childs & McNicholl, 2007). Their limited SMK constrained the development of their PCK that in turn affected their classroom practices. Teachers still needed to develop subject-specific PCK in Chemistry and they could not easily transfer and use their PCK, developed in their subject specialism, when teaching outside specialism. Their lack of content knowledge also affected their attitudes towards the subject because teachers became very anxious when teaching a subject they were less familiar with.

As a result, these teachers were experiencing tensions between their multiple identities, that is between being a 'specialist' teacher when teaching their subject specialism and a 'generalist' teacher when teaching Integrated Science. They were having difficulties negotiating what Hobbs (2013a, p. 292) describes as a "fully elaborated professional identity" that included looking at themselves as teachers of Integrated Science. They did not feel competent to teach all Science areas because they were experiencing discontinuities in their actions and interactions arising from limitations in their content knowledge and practices. The teachers became more anxious and frustrated when teaching outside specialism because they felt that they could not deliver and engage the students in the same way as within their area of expertise. Yet, these teachers need to cope with such challenges. They resorted to employing different strategies to overcome their difficulties.

Dealing with the Challenges

The three teachers made use of a variety of strategies when preparing to teach outside their area of specialism. These strategies could help them deal with difficulties that could arise when teaching their non-specialist area. In the following dialogue Laura, Maria and Robert talk about their coping techniques.

Laura: *When preparing for a Chemistry lesson I have to research a bit more than I would if am teaching my area of specialisation because certain things I forgot and I wanted to be sure that I am giving them the right information and that I am explaining things in the right way so they won't have misconceptions.*

Robert: *I feel better after I conduct research but there is more preparation. I have to prepare more and do a lot of research before going in class and do the lesson. I do not only prepare for the lesson and even for what students may ask.*

Maria: *I take twice as long to prepare a Chemistry lesson because I read a lot and use the Internet since I would like to have a background. I have asked my colleague to suggest simple experiments for the students to demonstrate simple chemical reactions and I use those in my lessons.*

Laura: *When I have difficulties I find it easier to ask my colleague who is a Chemistry specialist. She helps me a lot. We prepare lessons together and she suggests different ideas and explains what is going on in chemical reactions.*

Robert *I discuss some experiments with my colleague and I also get help from the lab technician. But I cannot do it all the time: asking questions like 'What are you going to do? How are you going to do this?' You need to cope on your own.*

Maria: *I find that some topics are easier to plan than others, like the topic of understanding matter because it is more related to Physics and I can use my Physics background.*

Robert: *Yes I use that strategy I try to make sense of things basing on what I know, like I will be trying to understand some Chemistry topics by using ideas from Physics.*

Laura: *With time I feel it is getting better… as time is passing it is becoming easier I think. You already know what students' misconceptions are and you already know how to handle them. I think the more time passes the more experienced you are.*

The teachers under review generally used the following four strategies to cope with teaching outside specialism. These included (1) conducting research through books or the Internet to improve their Chemistry content knowledge and to find lesson activities; (2) asking help from more experienced colleagues; (3) using knowledge from their own specialist subject area; and (4) repeated practice. One may describe the aforementioned strategies as support mechanisms or 'boundary objects' (Akkerman & Bakker, 2011) which can be human and non-human, such as artefacts and tools. These 'boundary objects' are important professional learning opportunities that enable teachers to cross the boundary between teaching the different science areas (Hobbs, 2011).

Teachers were very concerned about their limitations in teaching Chemistry topics. Conducting research from books or the Internet was the most common support mechanism used to address their weaknesses or gaps in knowledge and to find out interesting activities that could make their Science lessons more interesting. This was also one of the main strategies used by non-specialist teachers as described in the research carried out by Childs and McNicholl (2007) and Kind (2009).

Teachers also discussed their difficulties with their colleagues, being either subject specialists or laboratory technicians. They felt that they could easily discuss their difficulties without feeling embarrassed that they lacked knowledge in the subject. Consistent with the literature (Childs & McNicholl, 2007; Kind 2009, Helliar & Harrison, 2011; McNicholl et al., 2013), consulting colleagues like subject specialists and laboratory technicians is very common among non-specialist teachers. Teachers very often draw on and learn from their colleagues who are specialist in the area because it is often a quicker and more effective way of getting information (Eraut, 2007). Like in other studies (Childs & McNicholl, 2007; McNicholl et al., 2013) these teachers frequently asked their colleagues to explain both content knowledge and ways of

teaching particular concepts. In return, subject specialists helped the non-specialist teachers transform their subject content into ways of teaching it by discussing activities, experiments, analogies that promote student understanding. During such interactions teachers were learning both their SMK and PCK from the subject specialists. These interactions and collaborations showed that "PCK is created in practice" (McNicholl et al., 2013, p. 157). As reported by Hobbs (2013a), collegial support is necessary for teachers to gain more confidence and competence in teaching the subject. This can lead to "the development of a more positive identity in relation to the subject" (Hobbs, 2012, p. 28).

Besides conducting research, teachers also used their knowledge of their subject specialism to explain Chemistry concepts especially in topics which are related to each other. Non-specialists teachers generally use these strategies (Nixon & Luft, 2015) in order to build their knowledge base. On the other hand repeated teaching experience helped the teachers to gain more reassurance and increased self-efficacy in their work. These four support mechanisms enabled the teachers to build and refine their SMK and PCK so that they could develop better lessons when teaching their non-specialist area.

Conclusions and Implications

In their daily practices Maria, Robert and Laura were encountering a number of challenges when planning and teaching Chemistry topics compared to when teaching within their area of specialism. They had to learn different content knowledge and practices in the different Science areas. It is evident from their narratives that Maria, Robert and Laura were experiencing tensions between their multiple identities. This disrupts the 'rhythm' of the teacher, leading teachers to experience a discontinuity in their professional identity when switching from teaching within specialism to outside specialism (Hobbs, 2013b). In order to cope with teaching all the Science subjects teachers had to learn how to adapt to this situation by conducting research, learn from colleagues, use their own knowledge base and through repeating their lessons. Like Hobbs (2013a) I would argue that "how a teacher copes in these situations is critical not just to their practice but also to their professional identity" (p. 288).

For teachers to cross boundaries they must have flexible identities and be able to adapt to new situations. While these three teachers identified themselves as subject specialists, they were ready to make the shifts in their identity by

using support mechanisms to teach other Science areas. In fact, these teachers stated that they did not mind teaching other areas of Science as long as they conducted the necessary research and asked support from colleagues in order to feel prepared and more knowledgeable in Chemistry. Although these teachers were experiencing tensions within their own identity they were ready to cross boundary by transforming the challenges encountered and engaging in professional learning through the use of support mechanisms.

Participating in long term professional development can also be a powerful learning experience for these teachers. Taking an active role in their learning, discussing and finding ways to improve their practice and working in collaboration with other teachers will enable these teachers to negotiate and transform their identity as Science teachers by overcoming the challenges and tensions arising when teaching outside specialism.

References

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

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145-179.

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

Bennett, N. (1993). Knowledge bases for learning to teach. In N. Bennett & C. Carre (Eds.), *Learning to teach* (pp. 1-17). London: Routledge.

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

Carlsen, W. S. (1993). Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching*, *30*(5), 471-481.

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.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). London: Routledge.

Denscombe, M. (2014). *The good research guide: for small-scale social research projects* (5th ed.). Berkshire, England: McGraw-Hill Education.

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*. Retrieved from: 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.

Hatch, J. A. (2002). *Doing qualitative research in education settings*. New York: State University of New York Press.

Hashweh, M. Z. (1987). Effects of subject-matter knowledge in the teaching of biology and physics. *Teaching and teacher education*, *3*(2), 109-120.

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

Helms, J. V. (1998). Science--and me: Subject matter and identity in secondary school science teachers. *Journal of Research in Science Teaching, 35* (7), 811-834.

Hobbs, L. (2011). Factors influencing mathematics and science teachers' self-assessment as teaching'out-of-field'in rural and regional schools. In *AARE 2011: Researching across boundaries: Proceedings of the 2011 AARE International Research in Education Conference* (pp. 1-12). Australian Association for Research in Education.

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, Janice Langan-Fox & Cary L. Cooper (Eds.), *Boundary-Spanning in Organizations: Network, Influence, and Conflict* (pp. 7-28). New York: Routledge.

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.

Kind, V., & Kind, P. M. (2011). Beginning to teach Chemistry: How personal and academic characteristics of pre-service science teachers compare with their understandings of basic chemical ideas. *International Journal of Science Education*, *33*(15), 2123-2158.

Kind, V., & Taber, K. (2005). *Science: Teaching school subjects 11-19.* London: Routledge.

Lee, E., & Luft, J. A. (2008). Experienced secondary science teachers' representation of pedagogical content knowledge. *International Journal of Science Education*, *30*(10), 1343-1363.

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

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.

Millar, R. (1988). Teaching physics as a non-specialist: the in-service training of science teachers. *Journal of Education for Teaching*, *14*(1), 39-53.

Ministry of Education and Employment (MEE). (2012). A *National Curriculum Framework for all*. Malta: Ministry of Education and Employment.

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.

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.

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

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23.

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

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