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THE CHALLENGES FACED BY SCIENCE TEACHERS WHEN TEACHING OUTSIDE THEIR SPECIFIC SCIENCE SPECIALISM

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Abstract: Several research studies have been conducted with novice and experienced teachers when teaching within and outside their subject specialism. This paper aims to review a number of these studies and highlights key points concerning the teaching of different science subjects at secondary level and teachers' level of self-confidence. Teachers face considerable challenges when teaching outside their area of expertise. These challenges are mainly due to limited subject matter knowledge (SMK) in a particular science area. This will also influence the development of the teachers' pedagogical content knowledge (PCK) which is crucial in lesson preparation and in the way science teaching is conducted. Teachers have also developed a number of strategies to deal with such challenges.

Key words: teaching outside science specialism, self-confidence, pedagogical content knowledge**,** subject matter knowledge.

1. Introduction

Science teachers can teach different science subjects at secondary level. These teachers would usually have specialised in one particular area at University level. Therefore in many cases they will be teaching within their area of expertise or outside their subject specialism, meaning that one has not studied this subject at degree or at pre-university Advanced level. Teaching outside area of expertise offers considerable challenges and teachers express concern and apprehension when dealing this situation. Teachers' lack of confidence when teaching topics outside their area of expertise is manifested in different ways such as when preparing lesson plans, choosing or devising activities and analogies to aid students' learning, answering students' questions, setting up laboratory experiments, linking and applying various concepts and principles to everyday life situations, generating students' interest and passion for the science area. This article reviews various research studies conducted amongst novice and experiences teachers when teaching within and outside their area of expertise.

2. Challenges faced by teachers when teaching outside their subject specialism

Teachers teaching outside their area of specialism face considerable challenges in lesson preparation and science teaching. First of all these teachers need to understand the structure and nature of the discipline and learn unfamiliar content knowledge, which is known as subject matter knowledge. Secondly, they need to transform the content knowledge into suitable activities, analogies, demonstrations or simulations and adapt them to the different students' abilities to help them learn, what is described by Shulman (1986, 1987) as pedagogical content knowledge. This review sets out to outline the challenges faced by science teachers when teaching outside their area of expertise and explore the strategies used by teachers in dealing with such situations. Inadequate background in the subject knowledge is one of the main factors that contributes to such challenges and will have an impact on the development of the teachers' pedagogical content knowledge as well as on the teachers' self-confidence and attitudes when teaching topics outside their area of expertise.

The teachers' knowledge base strongly influences all aspects of teaching like preparation, planning and decision making regarding the choice of content to be learnt (De Jong, Veal, & Van Driel, 2002).

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The knowledge base for teaching is made up of seven categories, which include subject matter knowledge (SMK), pedagogical content knowledge (PCK), curricular knowledge, general pedagogical knowledge, knowledge of the learners and their characteristics, knowledge of educational contexts and knowledge of educational purposes (Shulman, 1987). According to Shulman (1986, 1987) SMK is based on two main areas: the organisation of concepts, facts, principles and theories and the nature and structures of knowledge which refer to the ways "in which truth or falsehood, validity or invalidity are established" (Shulman, 1986, p.9). In other words, the teachers' SMK incorporates not only knowledge of specific topics of the curriculum but also knowledge about the epistemology of science or the nature of scientific knowledge.

Therefore, one can argue that one of the most important characteristics of being a good science teacher is having a very good basis of SMK. However, research studies which have attempted to find a relationship between SMK and good teaching (Abell, 2007; Childs & Mc Nicholl, 2007; Hashweh, 1987; Kind, 2009) suggest that while a good background in SMK is a pre-requisite for good teaching it is not the only requirement. Kind (2009) contends that "high academic performance in a specialist subject is not an automatic precursor to good teaching" (p.1559). In fact, subject specialists are more likely to resort to teaching through a process of knowledge transmission which is not enough for deep learning to take place. Exemplary science teachers, as argued by Shulman (1986, 1987) also need to develop PCK which enables science teachers to blend "content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners and presented for instruction" (Shulman, 1987, p. 8).

Magnusson et al. (1999) describe PCK for science teaching as the transformation of several types of knowledge not only SMK. These knowledge areas consist of five components which include orientation toward science teaching, knowledge and beliefs about the science curriculum and assessment in science, knowledge about students' understanding and misconceptions of specific science topics and knowledge about instructional strategies for teaching science or topic specific pedagogy. PCK develops with teachers' experience (Abell, 2008; Davis et al., 2006). It is a cyclical process whereby teachers transform, reflect and evaluate their practice and continue to learn as they develop their practice. PCK is also content–specific or subject-specific knowledge that is fundamental for effective science teaching (Magnusson et al., 1999). Subject-specific knowledge entails general strategies applicable to teach science. Content-specific strategies, such as illustrations, models, analogies, experiments and activities are required when teaching particular topics within a science field. Abell (2008) acknowledges that PCK differs from one discipline to another, for example teaching biology is different from teaching chemistry. This implies that when teachers teach outside their area of expertise they also need to develop different instructional strategies (one of the components of PCK). Having a "limited knowledge of topic-specific representations can negatively impact science instruction" (Magnusson et al., 1999, p. 112).

Research studies about teachers teaching science topics within and outside their areas of specialism highlight important differences in the quality of preparation and delivery of science lessons. Common challenges encountered by trainee or experienced teachers can be identified from different studies (Childs & Mc Nicholl, 2007; Kind, 2009; Kind & Kind, 2011; Hasweh, 1987; Sanders, Borko & Lockard, 1993). The research study conducted by Hashweh (1987) with six experienced secondary school teachers preparing to teach topics within and outside their area of expertise showed remarkable differences in planning, response to students' questions and conduction of lessons based on their prior SMK. Within their field of expertise, teachers had a wide knowledge base of the subject, knew the subject in more depth and were able to draw links between different areas of knowledge in the same subject discipline. More knowledgeable teachers made many modifications to science teaching according to the way they developed their schemata of SMK. They could expand activities or generate their own activities, ask higher-level questions, detect students' misconceptions and deal effectively with students' difficulties. On the other hand teachers teaching outside subject specialism, with lower background SMK, followed the textbook structure quite closely, could not generate new activities and asked recall questions. They could not detect students' misconceptions and in some cases they reinforced these ideas. This is in line with another study conducted by Van Driel, De Jong & Verloop (2002) where teachers with good content knowledge were also more aware of the students'

difficulties and misconceptions and were able to make use of strategies to induce conceptual change. Kind (2009) also reported that trainee teachers felt less confident at trying out new things, were less creative and did not develop their own ideas in preparing lessons outside their area of expertise but followed the traditional methods. In a study by Childs & Mc Nicholl (2007) with novice and experienced teachers, it was reported that lessons outside subject specialism were tightly controlled and included less discussions, open-ended questions, anecdotes, illustrations and analogies. Practical work was closely directed and textbooks were used more often. "Lessons taught outside of subject specialism were perceived to be rigid and constrained" (ibid. p. 11).

One of the striking findings in the study conducted by Childs & Mc Nicholl (2007) was that teachers regardless of their experience faced similar issues and challenges when teaching outside subject specialism. These findings are consistent with the findings of another study conducted by Sanders et al., (1993) with three experienced teachers teaching within and outside their area of expertise. Experienced teachers sometimes acted like novice teachers when teaching outside subject specialism. They encountered difficulties in planning lessons because they were uncertain of the time required to develop different concepts, how to sequence the content, how concepts were interrelated and had difficulties in deciding what was important. Lessons outside area of expertise did not flow as smoothly as within their area of expertise. They made quick and frequent changes and were sometimes unable to build explanations in response to students' questions. Similarly, in other studies (Kind, 2009; Kind et al., 2011) trainee teachers were also concerned in answering subject-related questions and the ability to handle questions depended on their self-confidence.

When teaching outside subject specialism, lessons were more teacher-dominated and more time was devoted to teacher explanations (Sanders et al., 1993). Less risky instructional activities were planned for unfamiliar content as opposed to more student-centred activities and less teacher talk when teaching within familiar areas. However, experienced teachers could manage their classrooms better than novice teachers. They made use of their science process skills, lab organisation, handling equipment, classroom management and group arrangements better than novice teachers. Unlike beginner teachers they did not rely on textbook presentations but used various resources. Hence they were able to draw upon their general pedagogical practice to provide a framework for their teaching within and outside area of expertise and supplement it with content knowledge and PCK.

Practical work was another area of concern (Childs & Mc Nicholl, 2007). Teachers felt that they lacked knowledge about technical and safety details. They were also anxious about how to deal and explain unexpected or wrong results due to their lack of confidence in the subject. Experienced teachers were concerned about their ability to make links between the different areas of the science curriculum due to their impoverished view of the subject. Having an in-depth knowledge of the subject matter helps teachers provide alternative explanations or use different approaches to help students understand complex scientific concepts. Teachers felt restricted in their explanations, in the range of activities and illustrations provided when teaching outside subject specialism (Childs & Mc Nicholl, 2007; Kind, 2009).

The above studies construct "a picture of science teaching outside a teacher's subject specialism as limited, unadventurous and lacking cognitive challenge" (Childs & Mc Nicholl, 2007, p. 5). These studies show that the level of SMK greatly influences how the subject is taught (see Kind et. al, 2011). Davis et al., (2007) argue that "when teachers have a stronger subject matter knowledge, they are more likely to engage in sophisticated teaching practices" (p. 622).

3. Strategies used by teachers to deal with challenges when teaching outside subject specialism

When facing unfamiliar science content, teachers resort to a range of strategies to deal with these challenges (Childs & Mc Nicholl, 2007; Kind, 2009). During the planning stage, they mainly read textbooks, teachers' resource packs and schemes of work, which besides offering various ideas of lesson plans and activities; they also outline links between lessons across the topic. They also seek help and advice from school colleagues who are subject specialists, especially about practical work and conduct trail experiments. Support from the workplace was found to be the most popular strategy

to help teachers deal with their weaknesses in subject matter. Kind (2009) notes that about 50% of trainees actively sought advice from school colleagues when teaching outside area of expertise. On the contrary when teaching within their subject area, trainees read textbooks to gauge students' knowledge levels, relied mainly on their prior knowledge, consulted less their colleagues and rarely tested experiments prior to their teaching. Since trainee teachers consulted more resources when preparing lessons outside their area of specialism they produced more successful lessons. They managed to successfully transform the learnt SMK to PCK when they delivered lessons with suitable activities that met the students' learning objectives.

4. Teachers' self-confidence when teaching outside area of specialism

Some research studies have also attempted to find a correlation between teachers' self-confidence to teach the different sciences and the level of content knowledge (Appelton, 1995; Harlen & Holyrod, 1997; Kind et al., 2011). Studies with secondary school science teachers are scarce compared to studies carried out with elementary teachers. Appleton (1995) found that elementary teachers gained more confidence not only when they experienced success in learning science content but also when they experienced how the subject is taught after undergoing a science method course. This highlights the importance of developing PCK. Harlen & Holroyd (1997) state that "confidence in a specific area of content is closely related to knowledge of that content" (p.103). However, confidence is also influenced by other factors such as school and personal experiences, the nature of initial and in-service experience, pressure of curriculum overload, support from colleagues and material resources and the teacher's own view of professional capability. This last factor refers to the teachers' perceived self-efficacy. Bandura (1997) defines perceived self-efficacy as the "beliefs in one's capabilities to organise and execute the course of action required to produce given attainments" (p.3). The theoretical framework of self-efficacy is embedded in social cognitive theory. Self-efficacy beliefs have two dimensions. They indicate the level of self-confidence in teacher's own teaching abilities, known as personal science teaching self-efficacy (PSTE). They also reflect the belief that students learning can be influenced by effective teaching, which is known as the science teaching outcome expectancy belief (STOE). Teachers' behaviour is based upon these two dimensions of self-efficacy beliefs. According to Riggs and Enochs (1990) "teacher efficacy beliefs appear to be dependent upon the specific teaching situation" (p. 627). Therefore, teaching within or outside area of specialism will affect teacher's self-efficacy and self-confidence. In the study by Kind et al., (2011) some trainee teachers, preferred teaching their specialist subjects and were anxious in teaching the other sciences. Most trainee secondary school teachers in Kind's study (2009) expressed concern in answering subject-related questions on unfamiliar topics and worked hard to improve their knowledge weaknesses to gain confidence. Teachers' confidence when teaching topics outside their area of expertise is affected by the limited repertoire of appropriate explanations and demonstrations and by the limited ability to make the links between lessons and across scientific concepts (Childs & Mc Nicholl, 2007).

5. Conclusion

These research studies have shown that there are considerable differences when teaching within and outside area of expertise. Teachers seem to be more self-confident when teaching within their subject specialism. This phenomenon is present in many countries. In Malta many science teachers have a teaching degree specialising in Physics and Science. A number of these teachers would have never studied Chemistry at secondary level, since physics was the compulsory science subject. Hence many teachers teaching Integrated Science to students aged between 11-13 expressed similar concern, apprehension and lack confidence when teaching topics related to science areas that are not in their area of specialisation (Gatt, 2011; Mizzi, 2005). It would be interesting to conduct an in-depth research study with these teachers and devise strategies how such teachers can be supported in order to increase their level of confidence when teaching outside their area of expertise.

References

Abell, S. (2007). Research on science teacher knowledge. In Abell, S. And Lederman, N. (eds.) *Handbook of Research on Science Education*, p. 1105-1149. Mahwah NJ: Lawrence Erlbaum Associates.

Abell, S. K. (2008). Twenty Years Later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*, 30 (10), 1405-1416.

Appleton, K. (1995). Student teachers' confidence to teach science: Is more science knowledge necessary to improve self-confidence? *International Journal of Science Education*, 17(3), 357-369.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman and Company.

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.

Davis, E.A., Petish, D., & Smithey, J. (2007). Challenges new science teachers face. *Review of Educational Research*, 76 (4), 607-651.

De Jong, O., Veal, W.R., & Van Driel, J.H. (2002). Exploring Chemistry teachers' knowledge base. In Gilbert, J.K., de Jong, O., Justi. R., Treagust, D.F. & Van Driel, J.H. (eds). *Chemical Education: Towards Research-Based Practice*, p. 369- 390. Kluwer Academic Publishers: Netherlands.

Gatt, C. (2011). Integrated science in secondary schools: teachers' perspectives and views. Unpublished B. Ed dissertation, University of Malta.

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.

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

Magnusson, S. K., & Krajcik, J. J. & Borko, H.(1999). Nature, sources and development of pedagogical content knowledge for science teaching. In Gess-Newsome J. And Lederman, N. G. (eds). *Examining pedagogical content knowledge: The construct and its implications for science education.* p. 95 – 132. Dordrecht: Kluwer Academic Publishers.

Mizzi, D. (2005). Co-ordinated Science in the Secondary School, A Case Study of a Curriculum development Process. Unpublished M.Ed Thesis.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teachers' science teaching efficacy belief instrument. *Science Education*, 74 (6), 625-637.

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), 1–22.

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