
Science teachers' professional development in the light of activity theory

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Abstract: This paper is a review of 32 articles focusing on science teachers' professional development and guided by the following research question: 'How do science teachers in secondary education perceive their professional development and how does the Activity Theory interpret teachers' perceptions and highlights the contradictions that develop?' The findings indicate that no educational reform effort can succeed if it does not take into account the personal interpretive context through which teachers interpret their actions, participate in professional learning programs, integrate or reject modern learning theories. The supportive conditions for teachers' active involvement in experimentation and innovation are their participation in learning communities and the strengthening of school collaborative culture. Activity Theory highlights the contradictions of their professional development process, the aspects that enable or limit their teaching activity and the motivations that drive them to participate in professional learning programs and the dynamics of their zone of proximal development.

Keywords: professional development; science teachers; activity theory; science teaching; learning communities.

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1 Introduction

The present work is a literature review in the context of a dissertation research concerning Science teachers' professional development through environmental education by the lens of the Activity Theory. The main purpose of this review, which focused on the perceptions of science teachers about their professional development, was to frame the study within the 'body' of the relevant literature. In this review, science teachers' learning is connected to the sociocultural constructivist paradigm, with Vygotsky's ideas on learning and Engestrom's Activity Theory to be dominant. A science teacher is considered as an active learner in the learning process and knowledge is perceived as the construction of meaning and understanding through social interaction (Kalogiannakis and Papadakis, 2019). Science teachers construct knowledge through mediated acts, encounters with individuals and the settings in which they live and act. The research question that shapes up this review deals with way the international literature, by the lens of the activity theory – a sociocultural approach – studies the way that experienced science teachers learn. The structure of the review begins with the theoretical views about science teachers' professional development and the science teaching change as well as the Activity Theory. Follows by the methodology of the research, the presentation of the findings and the summary with the final conclusion about science teacher professional development.

2 Theoretical views

2.1 Professional development

International literature, as well as the UNESCO, highlights teachers' professional development as the main variable for the successful implementation of educational reforms in order to achieve quality education for the benefit of students (Sammons et al., 2007, Windchild et al., 2012). Teachers double role as a subject and object of change makes the professional development a field full of challenges and contradictions. Teachers' lifelong learning seems to be very important to perfect the quality of their teaching practice, although it is not a simple process as it concerns teachers' internal motivations, their self-efficacy and their professional agency. Traditional professional development programs have been criticised as ineffective in providing real and sustainable improvements, since they are not taking into account the teachers' experience (Van Driel et al., 2001), their motivations for participating in such programs, the process

through which teacher change occurs (Guskey, 2002), school culture, peer coaching, exploratory learning, collaboration. Contemporary perception considers a professional development program effective, when taking into account the above factors (Darling-Hammond et al., 2009). When the teachers' motivations and objectives for participating in such programs are not in line with those of the formulators and providers, they create tensions that can obstruct the teachers' desire to improve their educational practices (Papadakis et al., 2020). The conflict stems from the different beliefs of teachers and theoreticians about what is considered acceptable in theory and practice (Perry and Power, 2004). In order for the teachers' role in educational reform to be understood, Tobin and McRobbie (1996), propose an analysis of their knowledge of and views on their teaching practices. The dimension of teachers' professional agency (Billett, 2014, McNicholl, 2013) describes teachers as professional who have the power to act and influence matters, to decide and have their own views and perspectives on their work. Teachers agency affects their personal work, their participation in any educational change and their identity as practitioners. Teachers' professional development is a long term, collaborative process considered within the particular sociocultural framework where occur. Teachers are active learners who relate their prior knowledge to new experiences (Korthagen, 2017). Is a process that takes place in a particular context, the most effective form of teachers' professional development is related to their daily activities (e.g. an unplanned meeting with colleagues or parents). The teachers are understood as reflective practitioner who reflect on their teaching and the teaching of others (Papadakis and Orfanakis, 2018).

2.2 Science education

The emphasis on lectures as a means to transmit an inflexible mass of data and to learn principles and laws by heart, rather than an inquire-based learning about natural phenomena, remains a common characteristic in the way science are taught in all countries. This approach has been criticised as it has reduced the popularity of science among pupils, who often come to be learners with insufficient understanding of scientific concepts, illiterate citizens in science in a world with so many information (Osborne et al., 2003). Moreover, this school science culture may limit science teachers' expanding zone (Munby et al., 2000). Contemporary science teachings (Southerland et al., 2007), aim at ensuring student literacy exploiting inquiry learning as a key element of any science educational reform respecting the knowledge that students bring in the class. These ultimate goals depict a totally different view to the current situation in science teaching in many schools (Kalogiannakis et al., 2018). Most of the systemic reform efforts in teaching science haven't led to the desired results, because it is difficult to change teachers' historically and culturally constructed beliefs about what teaching and learning means (Windschitl, 2004), beliefs that pervade not only their practices but also official documents, school curriculum, educational material, the media (Papadakis et al., 2018). Science teachers find it difficult to apply inquiry-based teaching (Capps and Crawford, 2012) due to a lack of experience and knowledge (Asay and Orgill, 2010), and a simplistic understanding of what 'scientific method' means, and therefore need help in understanding the new educational approaches in science. For a new teaching practice to be viable, it is substantial to be understand that the class culture has a part in the construction of the new teaching, (Keys and Bryan, 2001) and that the teacher's practice

balances between student knowledge, knowledge of science, pedagogy, teaching methods and the school's 'code' (Barnett and Hodson, 2001).

2.3 Activity theory

Activity Theory, a promising member of the socio-cultural theories' family, is completing and stimulating the field of educational change research. Sannino & Nocon (2008) characterise research on educational change as limited for its poor course and its many failed attempts at change, since it has failed to incorporate the historical past or theorise the results resulting from the applied reforms. Activity Theory highlights the areas where research into educational change experiencing weakness to meet its goal (Lee, 2011; Postholm, 2015). It is not only a method of analysing quality data but also a methodological approach that helps teachers to understand their own and others working frameworks in order to accomplish change. The socio-cultural context in which we live shapes us but does not fully define us. If we know the ways in which knowledge is socially and culturally structured within the framework in which we live and act, we can examine and analyse the relationships and dystopias that develop inside the activity system and then make the right decisions for the necessary change. Although the use of Activity Theory in educational research (Roth, 2004; Roth and Lee, 2007) is increasing, research focusing on teachers and teaching in the field of science education is limited. Activity Theory takes into consideration and emphasise the structural, cultural and historical elements that give shape and form to science teachers' teaching activity. It also analyses the contradictions in the teaching system of science teachers. Contradictions are sources that restrict or modify the activity and, by addressing them, the system can be strengthened. Therefore, they can give a lot of impetus to the development and change of the activity system.

3 Method

3.1 Aim, objectives and the research questions

The aim of this literature review was to explore and illuminate the dark and vague field of science teachers' professional and to record, group and present the findings that answer the question: How do science teachers perceive their professional development and how the Activity Theory interprets these perceptions.

The research objectives were:

- Exploring teachers' perceptions of their professional learning and development
- The presentation of the ways in which teachers learn how to learn
- The emergence of the Activity Theory, as a method of analysis and as a learning theory, which illuminates the science teachers' perceptions about their professional development.

The research questions focus on the science teachers' perceptions about the value and way of their professional development and explore how Activity Theory highlights and interprets the contradictions of teachers' perceptions. The research questions were formulated as follows:

- 1) How do science teachers in secondary education perceive their professional development?
- 2) In which way do the science teachers of the secondary Education develop professionally?
- 3) How does the Activity Theory interprets teachers' perceptions and highlights the contradictions that develop?

3.2 Data collection rationale

To answer the research questions, the researcher contacted a research in the Scopus database via HEAL link (search conducted in the spring and summer of 2017) using the search strings, 'science teacher perceptions' 'professional development' 'Activity Theory.' The researcher also used Google Scholar to gain more results and the researcher use a new sting 'sociocultural theory'. The search focused on the years between 2000 and 2017 in order to find the most relevant articles, as research on teacher professional development by the lens of the Activity Theory – a sociocultural approach – is limited (Sannino and Nocon, 2008). In order to obtain an overview of previous researches published in international journals on the professional development of science teachers, the researcher obtained 157 results for all search series together and after reducing the search to 'secondary school education' 74 results. The exclusion criteria were concerned the online learning, non-experienced teachers, teachers from other disciplines than science. In this way, the present study focused on the perception of the experienced secondary science teachers about their professional development and the research was analysed by Activity Theory. Based on the summaries of the articles, researcher selected a total of 46 articles for detailed reading. After reading all the articles, a final set of 32 more relevant articles based on the selection criteria mentioned above, three of these articles contained reviews. These articles followed qualitative methods use sociocultural approaches and the Activity Theory as an analytical tool. The published studies came from the USA (8), Canada (6), UK (6), Spain (1) Sweden (1), Netherlands (3), Italy (2), Egypt (1), Saudi Arabia (2), Korea (1), Singapore (1). The selected assignments provided an insight into the research question of how science teachers learn and develop as professionals.

3.3 Analysis

The aim of the review was to identify and record the main findings of the studies presented in the 32 selected articles. The findings were grouped into two main categories based on the conclusions of every study (1) Factors of professional development, (2) The socio-cultural perspective for science teachers' professional development. The above two major categories were divided into sub-categories. The first category 'Factors of Professional development' resulted in the following four sub-categories: (1) Educational learning communities, (2) Individual learning enhancement factors, (3) Obstacles and incentives for professional development, (4) Connecting theory to practice. While the second category 'Socio-cultural perspective for professional development' formed the following two sub-categories (1) The way teachers learn, (2) The potential of activity theory for educational change. These sub-categories shaped the presentation structure of this literature review. The purpose of the presenting review is to give an overview of the

way in which sociocultural perspectives interpret teachers' perceptions of their professional development and the factors that shape positive or negative learning conditions. In addition, the dynamics of Activity Theory is presented as an emerging learning theory but also as an effective method of analysis.

The findings were grouped into thematic fields which complement each other and none function independently of each other:

- The way teachers learn
- Educational learning communities
- Individual learning enhancement factors.
- Obstacles and incentives for professional development
- Connecting theory to practice
- The potential of activity theory for educational change

The three articles that present reviews have their own structure based on the articles they have studied. The summaries of these three reviews come to emphasise the present literature research and help to understand in which way teachers learn and how the Activity Theory interpret their perceptions.

4 Findings

4.1 The way teachers learn

Change is an empirical, gradual and difficult learning process (Bakkenes et al., 2010) and in order for it to be sustainable, teachers must regularly receive feedback on their pupils' learning progress and be constantly informed, supported and pressured. The cause of the difficulties lies in the contradiction of the students' double role as objects of teaching and as voluntary participants in the learning community (Beatty and Feldman, 2012). The incentive for teachers to adopt new practices is to accept learning as 'what pupils try to achieve' rather than 'what teachers engender'.

The way a teacher adopts the new method involves three phases. Initially, the activity system transforms and initiates the new method into teaching activity system as an extra object, causing contradictions between the two systems (the initial and the new). The teacher, in order to solve this imbalance, either rejects the new approach or learns to use it. The tension between the new method and other constituent parts of the system lead the teacher to one of three solutions: rejection, preservation and change. If the activity system moves towards change, the contradictions between the changing system and other school activity systems that remain constant may cause more extended change (Beatty and Feldman, 2012).

Teachers' professional development is a lifelong process aimed at developing their skills, knowledge, expertise and other characteristics as practitioners. Emphasis should be placed on the knowledge and beliefs of teachers at all stages of the reform, peer-to-peer cooperation and exchange of views should be encouraged and time for change to take place should be provided (Van Huizen et al., 2005). Changing the school is a multi-level, multi-thematic, temporally and spatially distributed, gradually increasing and radical

phenomenon (Hubbard et al., 2006). This could be due to the interaction of multiple change mechanisms, such as the prevailed and the non-prevailed activity (Sannino, 2008), the school's and the researchers' activity systems, (Nocon, 2008) school and university activity (Nilsson, 2008) and the relationship between schools, universities, families, experts, outside communities and organisations.

4.2 Educational learning communities

Teachers' engagement in collaborative communities (James and McCormick, 2009; Sales et al., 2011) influences their practices by enhancing students' achievement (Lawrence and Chong, 2010). Teacher participation in collaborative planning activities (Barma and Bader, 2012) implementation, reflection and collegial exchange of experience influences the development of Pedagogical Content Knowledge (PCK) (Forbes et al., 2009).

Teachers' ideas about what is effective teaching for their pupils and what, how and why they learn in the school they work on, are influenced by the context in which they are integrated, by the phase of their lifework, their experience, their practical knowledge and their students (James and McCormick, 2009). An important factor is the school's ability to support teachers' professional learning and to entail them in collaborative and mutual activities (Opfer et al., 2011). In order to create a learning and experimentation environment, external factors, such as time available, must be related to internal or personal circumstances (expectations for the network, past experiences). A teacher's development is a horizontal, continuing, holistic procedure in which they learn to behave in a way that is accepted by the teaching community and the society (Saka et al., 2009).

Educational programs should highlight the appropriate and productive patterns of socialisation (Mansour et al., 2014) and participation in professional communities and the importance of learning by other more experienced members of a community (i.e. school and other communities in which they are members). One way to promote professional development is to participate in school networks or learning communities, which enhances their external self-efficacy (i.e., they feel comfortable talking about their work, sharing ideas with colleagues, being noticed and participating in the professional development) and their internal self-efficacy (i.e. they feel comfortable with their own teaching practices). Educational communities bridge the gap between research and practice because they provide space for discussion and exchange of experiences about everyday problems faced by teachers in the classroom, connect their teaching practice with pedagogical content knowledge, promote transformative teaching and improve students learning. In general, when teachers participate in educational communities, their resistance to change and innovation decreases (Van Huizen et al., 2005).

4.3 Individual learning factors

Teacher agency is a factor of educational change and it is expressed through personal work, participation in an educational reform, the discussion and reflection of their identity as practitioners (Tobin, 2012; Vahasantanen, 2015). Professional development programs should support teachers' agency by providing opportunities, dialogue, time and opportunities to determine anew their identity and viewpoints on reform and integrate change efforts in their teaching work. Teachers' self-confidence is a lever to change their perceptions of their agency and their potential for action, and is built with the opportunity to experiment in the classroom, to gather evidence on the subject, draw conclusions, and

most importantly, do it all within a collaborative environment. An important element of agency and ability to explain collaborative learning is the use of the knowledge and experience of each member of the group, which is disseminated and distributed throughout the group and is available to everyone (Edwards and D'Arcy, 2004). Programs that led teachers to find out by themselves the gaps they might have without pointing out shortcomings and criticising, gave them the chance to develop more sophisticated perceptions of their teaching methods (Mansour, 2013; McNicholl, 2013; EL-Deghaidy et al., 2015).

4.4 Obstacles and motivations for professional development

The mediating role of teachers in active and inquire based learning differs from their traditional role as an official expert on knowledge who imparts it to the pupils, while the role of students as autonomous learners contradicts their traditional role as passive knowledge recipients (Feldman and Weiss, 2010; Beatty and Feldman, 2012). Obstacles are the insufficient time to implement and adopt the method, the effort required by the new method, the sense of loss of control in the classroom, the style of teaching that may not match the new method, their inability to share experiences and ideas with colleagues and the insufficient support from school leaders (Beatty and Feldman, 2012). Teachers need incentives to adopt new ways of teaching (Sannino and Nocon, 2008). What incentivises teachers to participate in a professional development process is their understanding that the program will expand their knowledge and their skills and enhance their efficacy in the classroom (Barma and Bader, 2012; Barma, 2011).

4.5 Connecting theory to practice

To close the gap between theory and praxis (Korthagen, 2017) for science teaching, teachers' knowledge (Keys and Bryan, 2001), school culture and the role of teachers in developing knowledge and facilitating change are considered important elements (Groundwater-Smith and Mockler, 2011; Brown and Crippen, 2016). Yamagata-Lynch and Haudenschild (2006) found that the teachers' incentive and aims to participate in professional development programs are not corresponded to the experts that shape and implement them, resulting in tensions that can turn to obstacles. The conflict between teachers and theoreticians of education stems from their not the same point of views about what is considered acceptable in theory and praxis (Perry and Power, 2004; Nilsson, 2008). These tensions give rise to doubts as to what are the appropriate pedagogical practices and create a gap in determining the quality of teachers. Teachers do not believe that research can contribute to the daily lesson, perhaps because research gives teachers great lists of what they 'should do'. The driving force behind sustainable change is the collaboration of teachers and researchers in the joint design of learning tools (Bjonness and Johansen, 2014). Educational tools link what we know and apply to educational theory, therefore, they are agents of change in the classroom. The teacher should be able to use these tools in everyday practice and adapt them to some other teaching, as a tool has the ability to move from one situation to another. Besides, the sustainability of innovations also involves disseminating and adopting them from environments other than those in which they originally developed (Sannino and Nocon, 2008).

4.6 The potential of cultural–historical activity theory for educational change

Studies on educational change fail to fully analyse the context of change, leading to fragmentary analyses and neglecting cultural and historical conditions that reinforce or inhibit change (Lee, 2011). There is a tendency towards simplification rather than adopting complexity. Accepting stereotypical generalisations, models, or theories focuses on an average that does not even carry a universal truth. It does not analyse the influence of power and politics. Although teaching and learning are purely social efforts, rational models avoid the dimension of emotions and identity (Van Huizen et al., 2005). The speed with which new methods and practices are often introduced, is not taken into account. Compared to generalised models that try to describe and explain the change of school, the CHAT methodology initially appears complicated precisely because it examines complex social systems (Forbes et al., 2009). The different perspectives of the participants in an activity system emerge clearly and the tensions and contradictions become apparent. The picture provided offers opportunities for reflection, thus stimulating professional training (Yamagata-Lynch and Haudenschild, 2006). Researchers for science education have not yet exploited it to understand the learning process and to plan practical changes (Roth, 2004). As in any theoretical context, there are restrictions on how CHAT can be applied as it focuses on specific and localised social practices rather than on ‘society’ as a whole.

5 Meta-studies

Postholm (2012) in a review on 31 studies focusing on the in-service science teachers' professional development, point out that the prerequisite for teachers to learn and change is to change the culture and structure of the school (James and McCormick, 2009), while innovations fail because they do not consider the way teachers learn. Teachers want to work on topics of interest based on their teaching experience, they want to define their own learning goals, they want collaborative professional reflection on their practice of changing and developing their teaching. Teachers learning to self-regulate their own learning process become researchers of their practice. Important personal factors for the professional development of teachers are their cognitive, functional, emotional aspects and motivations (Hoekstra and Korthagen, 2011; Vygotsky, 2000). External factors are the common vision, the positive school climate and the help of the school leadership (Buczynski and Hansen, 2010). The collectivity and self-efficacy of teachers are enhanced by collaboration. Educator knowledge is being promoted and put into practice when shared with teachers and the right way to do this is to have teacher educators involved in interacting with teachers (Opfer and Pedder, 2011). Schools in which teachers work are the ideal field of training (Sales et al., 2011).

Timperley et al. (2007) in a study of 97 articles state that teachers' professional development is affected by their available time, the involvement of external experts, their active and conscious involvement in the process, their participation in learning communities, the positive school culture which encourages their effort and finally the context of learning to be in line with their problems and interests. Teachers involved in professional development programs need strong motivation so as to change and perfect their practices. The objectives of the program must be in line with teachers' objectives, the new learning must concern real teaching settings that they face in the classroom, the

educational material must be relevant to what concerns them while issues of inquiry-based teaching as well as the connection of their practice with learning theories must be the subject of continuous discussion and reflection.

Roth et al. (2009) presented a review of research on Science Education by the lens of the Activity Theory. They divide their research results into five major and sometimes overlapping categories. The first category concerns the mediation of educational tools in different teaching environments, emphasising the tensions between the tools and other elements of a teaching and learning activity system. The second category emphasises the way in which the school as a social structure and system, and society mediate and influence learning in the classroom or on an individual level. The third category concerns the way a teaching issue is involved in different activity systems. The fourth category examines the active and meaningful participation of students in learning processes of teaching Science. The fifth category concerns the way in which CHAT, as a Theory of Praxis, works as an instrument for changing Science teaching and the world at large

6 Conclusion

Teachers' professional development is central to improving their effectiveness, which is a complex process (Papadakis and Kalogiannakis, 2017, 2019). Facing the development system of science teachers as the smallest unit of analysis, there is no point in trying to increase declarative and procedural knowledge. Educational change is primarily an empirical learning process, a set of contradictions that demand understanding to lead to expansive learning (Dorouka et al., 2020). Efforts fail because they do not take into account the way teachers learn, the culture and structure of the school, the learning communities, but also personal factors such as motivation, professional agency, beliefs and perceptions. The analysis of the contradictions highlights the elements of the science teachers' teaching framework that permit or not their zone of proximal development.

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