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DEFINING TEACHER OWNERSHIP: A SCIENCE EDUCATION CASE STUDY TO DETERMINE CATEGORIES OF TEACHER OWNERSHIP

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Abstract. *This study seeks to put forward a justified definition for the concept of Teacher Ownership, and establishes levels of science teacher ownership, based on a hierarchy of categories, using phenomenographic analysis. Such ownership is based on a meaningful science teacher internalisation of a motivational context-based teacher approach, established via a prior CPD programme. In so doing, the study distinguishes between teachers' self-efficacy levels attained at the end of the CPD and teacher ownership indicating the capability of propagating the desired teaching to students and other teachers. The phenomenographic analysis, based on semi-structured interviews, is carried out with 10 science teachers, 3 academic years after the administered CPD programme. From an analysis of perceptions, 3 distinct categories of sustainable science teacher ownership, based on 5 distinct teaching dimensions, reflect variations in orientation of teacher ownership. The main conclusions are that sustainable teacher ownership differs from terms such as a sense of ownership, towards ownership and self–efficacy and that, in this study, teacher ownership can be described as being exhibited by the science teachers in paradigmatic, experiential and emotional ownership categories.*

Keywords: *phenomenographic analysis, self-efficacy, teacher ownership, teacher ownership categories.*

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Introduction

In our rapidly changing world, there has been a growing need to re-consider the role of science education within quality education, which has led to a range of visions and even to paradigm shifts in curricula and science teaching. For implementing a paradigmatic change within science education, at both philosophical and operational levels, it is obviously important for teachers to reflect on their educational beliefs and changes needed in ways to engage in refocusing their teaching. This suggests the need to provide effective, authentic training courses, or long-term continuous professional development (CPD) programmes for science teachers (Darling-Hammond et al., 2017; Desimone, 2009). The CPD effectiveness can be associated with a teacher expressed change of beliefs and the adoption of alternative actions, based on such beliefs (Posnanski, 2002).

However, besides stating such beliefs and associated operational changes, including the formulating of new approaches to the teaching of science, it is important to go further and to seek to determine the internalisation of such beliefs, thus identifying permanent teacher philosophical beliefs and the associated self-owned operations (Rannikmäe, 2001). This further step can be considered as reflecting true teacher ownership, which is seen as above and beyond a level of self-efficacy in comprehending CPD ideas propagated by others. In so doing, it expresses an internalisation of the conceptualisation of the change in teaching as befitting sustainable teacher ownership, rather than, at best, a sense of teacher ownership coming from repeating statements from others.

Research Focus

This study aimed to distinguish between a teacher's post-CPD self-efficacy status and the attainment of a sustainable level of teacher ownership based on underlying philosophical ideas, in this case, related to a motivational

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context-based, science teaching approach (Valdmann et al., 2016), after reflection and teaching over a period of time, post-CPD.

The research questions put forward were:

1. In what way can sustainable teacher ownership be meaningfully defined, distinguishing this from teacher self-efficacy and a 'sense of ownership'?
2. What characteristics of science teacher ownership based on dimensions of variation can be determined 3 years post-CPD, designed to operationalise a philosophy and teaching approach?

Theoretical Overview

Teacher Ownership

Ownership, as a term, is often used in legal circles and in psychology, less so in education. Pierce et al. (2003) defined psychological ownership as:

'*The state in which individuals feel as though the target of ownership, or a piece of that target, is* '*theirs*' (p. 86).

Such ownership goes beyond materialistic ownership, or ownership of specific developments and can relate to an internalised ownership that aligns with an intended philosophy and, within education, a teaching approach. Applying this vision to teachers as individuals, with their conceptualisations portrayed by the philosophy they hold and the internalised vision of science teaching they promote, this can be labelled 'teacher ownership'.

Ketelaar et al. (2012) considered teacher ownership as a 'mental or psychological state' that captured a teacher's conceptualisation with regard to an innovation. The incremental movement from exposure towards sustainable ownership of an innovation, such as a new philosophical viewpoint and its subsequent operationalisation, was suggested to start when teachers felt an effort succeeded, teachers felt it belonged to them and was not simply imposed on them (Ogborn, 2002). Teacher ownership of an innovation, such as implementing a new philosophy using a suitable teaching/learning model, was thus seen as more than a belief (confidence) in one's abilities (competence) influencing "motivation to act" i.e. it needed to be seen as a stage beyond self-efficacy as put forward by Bandura (1977). It was an internalisation of the conceptualisations involved to such a degree that this recognition could be expressed to others. This suggested that teacher ownership is associated with "innovation to act" (Pierce et al., 2003).

In the literature, teacher ownership seemed to be portrayed from three perspectives:

a) A sense of ownership.
b) Towards teacher ownership.
c) Appropriate, permanently attained attributes – sustainable ownership.

The literature pertaining to teacher ownership largely focused on gaining a 'sense of ownership', the teacher 'feels' they gained some form of ownership often emanating from a continuous professional development programme (Blonder et al., 2008; Ketelaar et al., 2012; Kyza & Georgiou, 2014; Saunders et al., 2017). This 'sense of ownership' could refer to the classroom operational level or pertaining to a curriculum innovation. In this way, as Blonder et al. (2008) pointed out, a 'sense of ownership' could occur at the individual level, or through exposure, to the school and system levels. A 'sense of ownership' could derive from an innovation and an approach being deemed to be acceptable to teachers and hence a derived sense of self-efficacy. Thus, when most authors referred to a sense of ownership (Blonder et al., 2008; Ketelaar et al., 2012; Kyza & Georgiou, 2014), they were probably seeing this as equivalent to self-efficacy (Bandura, 1997). According to Bandura, self-efficacy was the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations.

In other words, self-efficacy was a person's belief in his or her ability to succeed in a particular situation. Bandura described these beliefs as determinants of how people thought, behaved, and felt. Thus, for the teacher, the beliefs were largely based on self-reflection.

Between the 'sense of ownership' and sustainable teacher ownership, a 'towards ownership' concept (Hofstein et al., 2012) could be considered. Here, there was recognition that further steps beyond self-efficacy were needed and that the final ownership level had yet to be reached. These permanent attained attributes, as indicated by a sustainable teacher ownership, were being able to internalise the ideas as intended, put them into operation as expected and also to be able to teach others, as per the intended philosophy and approach. Rannikmäe (2001) recognised that as change took place over time and required indicators beyond an initial trigger, permanent ownership was a further step beyond any teacher guidance, such as CPD, and described the degree to which purposeful teaching, as seen by the teacher, was explicitly along the lines of a philosophy and approach provided

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by the initial trigger (e.g. a CPD course). This suggested permanent ownership was far from a measure of success from CPD involvement and it depended on the teacher's perception and enactments. Thus, it was more appropriate to measure the categories of sustainable teacher ownership developed by a teacher associated, for example, with a new teaching approach and philosophy. Such development and self-evaluation was seen as taking time and hence any determination of teacher ownership, in the sense of permanency, needed to be considered after a period of consolidation and reflection and it was probably that at least one year, after the end of any intervention (e.g. CPD course), was needed. This further suggested that neither a 'sense of ownership' or 'towards ownership' reflected the permanency of actual operational beliefs of the teacher.

The concept of sustainable teacher ownership related to both the beliefs established by the teacher and the operationalisation of these beliefs, which could be demonstrated in the classroom or to other teachers through CPD involvement. Such a concept seemed to be absent for the literature. The literature gave little recognition to the suggestion that CPD driven gains were not likely to be permanent, unless the teachers internalised these ideas and sought to put these into operation in a theoretically justified manner.

Motivational, Context-based Science Teaching (MCST) Approach

The MCST concept (Valdmann et al. 2016) was based on 3 major theoretical considerations:

- self-determination theory (SDT) (Ryan & Deci, 2000), whereby the promotion of students' intrinsic motivation was seen as important in enhancing three self-determination attributes – autonomy, competence and relatedness;
- promoting instructional improvements (Deci, 2009) that focused on students' active engagement, aligning the learning with curriculum intentions and ensuring appropriate rigour in providing students with meaningful challenges within the zone of proximal development (Vygotsky, 1980);
- a vision of science curricula that stressed learning utilising an 'education through science' emphasis (Holbrook & Rannikmäe, 2007), paying attention to the development of students' personal, social, as well as, scientific cognitive endeavours. The proposed 'nature of science education' was thus not about stressing the ways of the scientist any more than history was seen as taught for students to become historians, or language taught to become linguists, but it was proposed that science in school was part of the education provision and any science content was gained so as to enhance education in the nature of the subject, plus the personal and social domains (Holbrook & Rannikmäe, 2007).

In the MCST approach, the vision was meaningfully promoted via a 3-stage teaching-learning model (Holbrook & Rannikmäe, 2010), in which:

- Stage1 focused on the motivational engagement of students, initiated through teaching via a social concern, or issue, but having a scientific component. This, together with teacher scaffolding (raising the competence of students with peer support), was intended to set to the scene for aligning science learning with curriculum intentions and the focus for the learning that follows.
- The second stage promoted the intended science conceptual learning, perceived by students as having relevance, based on scientific questions emanating from stage 1, and where the teaching approach sought to be student-centred, inquiry-based and ensuring the rigour needed for establishing self- determination.
- Stage 3 built on the science conceptual learning and applied this to the social circumstances, through argumentation based on the initial situation so as to derive a consensus, socio-scientific decision and enabling the societal relevance of the learning to be enhanced.

Research Methodology

General Background

Though a post-CPD study, this study sought to distinguish between a teacher's post-CPD self-efficacy and the concept of sustainable teacher ownership of the underlying philosophical ideas, in this case related to a motivational context-based, science teaching approach (Valdmann et al., 2016). The study sought to recognise such teacher ownership, 3 years after the end of the CPD, seeking to identify differing conceptualisations by means of a phenomenographic analysis approach.

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Participants

Ten teachers, voluntary participated in this study. All teachers had participated in a one-year in-service CPD course prior to this study (Valdmann et al., 2016) and were interested in exploring implementation of the CPD ideas in practice. In the initial CPD course, all teachers had been introduced to, and became familiar with, a motivational, context-based, science teaching (MCST) approach, based on an Education through Science (EtS) philosophy (Holbrook & Rannikmäe, 2007). Three years after the end of the CPD, all 10 teachers were approached and asked to report how they incorporated the MCST approach in their teaching, interacted with each other and interacted with other teachers during science teacher meetings over the previous 3 years. At the time of the study, all teachers had more than fifteen years of teaching experience; two teachers taught only biology, three teachers taught only chemistry, while five taught a combination of different subjects (science, biology, chemistry, physics or agronomy). Four of the teachers taught at the middle school level (grades 7-9) and six at high school (grades 9-12) level, as indicated in Appendix 1. All teachers volunteering to participate in the study, as per the norm for Estonia, had a master's degree and were female.

Instrument and Procedures

The study followed on from a previously described CPD course (Valdmann et al., 2016), in which the design, operation and self-efficacy outcomes were indicated. The CPD had been planned based on outcomes of a Teacher Needs Questionnaire (Holbrook et al., 2014) using a constructivist, socio-cultural professional model (Howe & Stubbs, 1997) and taking into account Bandura's (1977) self-efficacy determinants.

Data for this study were collected towards the end of the school year, three years after the in-service CPD course, which ended in 2015. From the 27 original teachers involved in the CPD, 10 teachers voluntarily agreed to be involved in an individual, semi-structured interview, which focused on determining their perception of, and their ownership towards, the ideas put forward during the original CPD and allowed the interviewer to ask clarification questions. One interview lasted approximately one hour, and all 10 interviews were conducted over two consecutive days by the first author in similar conditions as in usual out-of-school meetings. All interviews were audio recorded and transcribed verbatim. All teachers agreed to a recording of the interview being made and all were assured that the data collected would be kept confidential and teacher names would not be disclosed.

The major question verbally asked during the semi-structured interview was:

'Describe how you applied the MCST approach in teaching the last topic you taught?'

This requested the teachers to reflect on their teaching and, in the context of the latest MCST module taught, to indicate their major teaching emphases and how effective they considered this to be. Where teachers were not sufficiently specific and a deeper understanding of the aspects being presented was needed, one or more additional questions were asked, based on the teacher's response. These additional questions tended to relate to the philosophy behind the MCST approach e.g.

1. What were the goals for teaching the latest module?
2. How did you motivate students? (Related to MCST, stage 1)
3. How did you use inquiry-based teaching? (Related to MCST, stage 2)
4. How did you incorporate any decision making in the teaching? (Related to MCST, stage 3)

Data Analysis

Familiarisation with the empirical material obtained was undertaken by two independent science education researcher staff from the University of Tartu who independently undertook steps 1-3 as indicated below and then jointly collaborated in the remaining steps.

1. Read the whole text.
2. Read again and mark where the interviewee gave answers relevant to the main interview question.

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3. In these passages the researchers looked for the focus of the teacher's attention which could indicate meaningful aspects in the teaching approach described. A preliminary code was given for each meaningful description related to each teacher's predominant way of understanding MCST.
4. These coded descriptions were put into categories, based on similarities and differences. Categories description units were re-coded to better fit the description.
5. Dominant areas of responses were discussed into which descriptive categories could be meaningfully sub-divided.
6. The agreed responses areas were labelled as specific dimensions of variation, which were taken to be meaningful for pointing to the teachers' variation in implementing MCST.
7. Labels (initially codes but later descriptive names) were assigned to each category of description.

Based on the above, the most important descriptive elements of the responses, by each teacher, were coded. Where appropriate, responses deemed to be sufficiently similar, were condensed into a single code agreed by the 2 researchers. The coded responses were compared and discussed between the researchers, recoding as appropriate, so as to minimise the categories of responses.

From analysing the transcripts, 7 separate areas of responses (labelled dimensions) were initially identified by agreement between the researchers, although these dimensions were subsequently reduced to 5, after discussions and re-interpretations were considered. The researchers eventually agreed that 5 dimensions accommodated the clarity and diversity of the teacher comments. These 'dimensions of variation' were identified as: *reflection type, student's motivation, inquiry activities, student decision making, and purpose of teaching.*

The process of analysing data was iterative and comparative, involving continuous sorting and re-sorting of the data. This process was undertaken several times, comparing teachers' answers associated with categories. The major dimensions of variation were finalised only when they led to agreed characteristics of different categories within a dimension, enabling a hierarchy of the categories to be established. The discussion continued multiple times arranging and rearranging the category descriptions until not only were the categories of responses minimised, but also aligned with meaningful levels of sophistication. Insofar as meaningful diversity permitted, three categories were eventually agreed among the researchers for each dimension of variation. However, in cases where the description of categories from the teacher responses were found to be overlapping, care was taken to ensure meaningful differences were established across at least 2 of the 3 categories per dimension of variation, as illustrated in table 1. As a final stage, the categories were compared and contrasted, to enable meaningful describing of the categories' similarities, while also identifying their uniqueness.

The hierarchical nature of the eventual categories of ownership was established as one of the leading principles in the analysis. This led to three categories being created.

Validation of the Data

The validity and reliability of the data was given strong consideration by the careful coding and re-coding of the teacher responses to the semi-structured interview questions, seeking to capture the teachers' intentions. The interpretation of the teacher responses was undertaken initially, by two researchers working independently, both having been present during the interviews. Nevertheless, the trustworthiness of the operation rests with the reader's recognition of the ability of the researchers. This is recognised as a potential area of concern in phenomenographic analyses (Cope, 2004). The researchers analysing the data were University science educators with at least one having prior expertise in undertaking phenomenographic research.

Research Results

By analysing the data from the semi-structured interviews and subsequently grouping the teacher responses into three categories. These three categories, related to the orientation of the teacher comments during the interview, were as indicated in table 1 and labelled (a), (b) and (c) - the latter being recognised as the highest category with respect to teacher ownership. Table 1 thus highlighted the hierarchical nature of categories, which was established through a phenomenographic analysis as one of the leading principles. These categories were then sub-divided into dimensions of variation that meaningfully characterised the teachers' operationalisation of the MCST approach. The five dimensions of variations identified were labelled: reflection type, student motivation,

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inquiry activities, student decision making and purpose of teaching, based on the philosophical ideas integral to the three teaching stages associated with MCST.

The major dimension of variation was the reflection type, giving distinctive descriptions for teachers within each category, meaningfully amplified from the semi-structured interviews. For the other dimensions of variation, the categories often described more aspects than put forward by an individual teacher, but were meaningfully grouped to form a meaningful hierarchy.

Table 1
Descriptive summary of each category for the five dimensions of variations

	Dimensions of Variation	Categories		
		a	b	c
1	Reflection Type	Reflected on the effectiveness of the teaching through emotional comments related to the instruction and student attitudes towards the topic.	Besides aspects under (a), teachers also identified promotion of education competences, such as student problems and how to handle these i.e. the focus is on ensuring students were able to learn from their experiences.	Besides aspects under (a) and (b), teachers also extended reflections to include future considerations i.e. how they would handle such teaching in the future, and also paid attention to moral and ethical implications of the topic.
2	Student motivation	Began teaching by asking a science, or everyday life, question, or by using novel teaching methods (utilising an app on their mobile phone, students acting drama).	Began teaching by asking questions from everyday life (exploring social aspects) or relating to a socio-scientific issue.	Began teaching by introducing a socio-scientific issue.
3	Inquiry activities	Saw the undertaking of inquiry activities as a way of making the learning more attractive to students	In carrying out inquiry activities, stressed the development of problem-solving skills so as to better conceptualise the science ideas.	Stressing problem-solving skills to better conceptualise the science ideas and the interconnection of these with appreciating socio-scientific issues within the society.
4	Student decision making	Undertaking decision-making in tackling scientific problems, or everyday life problems (as opposed to socio- scientific issues), or no decisions made.	Undertaking decision- making related to issues arising from everyday life in which science plays a part.	Undertaking justified socio-scientific decision-making, related to issues, which involved science alongside other issues arising from the society at the local, national, and global level.
5	Purpose of teaching	Dominance placed on subject content knowledge.	The purpose is seen as developing self- regulatory skills and gaining knowledge for future learning.	The purpose is seen as developing self-directed learning (learn to learn; lifelong learning; becoming a responsible citizen) and thus including a wide range of science-related skills, but also oriented to include social and value judgements.

Illustrative Descriptions of Examples for the 5 Dimensions of Variation

The following examples illustrate typical teacher responses in each of the 5 dimensions of variation. The teacher responses are captured within one of three category types, based on the responses provided by each teacher. While examples are very distinctive for the reflection dimension, they offer less clarity for other dimensions and perceptions within category types sometimes overlap.

Examples for the dimension "Type of reflection", describing how teachers reflected on their teaching.

Associated with category (a) – illustrating that teachers only reflecting on the effectiveness of their teaching. Teachers emphasised how happy, or unhappy they were when implementing the MCST approach. Teachers emotionally reported on the students' description about the effectiveness of their instruction.

> *"Students felt bad about the environment and because the summer was coming, the teacher allowed every student to search for information on a single insect. It was well done. Also, the presentations were interesting. At the end, the students created a crossword on insects. It was attractive for students." (Informing about effectiveness - Comment by teacher T10)*

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Associated with category (b) – reflecting on teaching effectiveness and identifying, or dealing, with problems. Teachers reflected on aspects of the teaching that went well, or badly and clearly articulated problems. However, such teachers did not offer solutions to the problems. The reflection indicated the teachers recognised inconsistencies between the espoused 3-stage approach and what was actually undertaken in the classroom.

> *"Students learned the factors affecting the rate of reaction. At the beginning, I used a tutorial video, in which there were many bangs; this attracted the attention of the students. Problems arose in planning the inquiry. Students did not understand fixed and variable factors, as well as their importance. Putting forward the research question was problematic, although this was practiced during the entire school year."*
>
> (Identifying or dealing with problems - Comment by teacher T7)

Associated with category (c) – not only reflecting on effectiveness and problems encountered, but the reflection extended to include future considerations. Teachers engaged in critical reflections about the moral and ethical implications of their teaching, describing action to take to change the situation in the future and adopt a wider position about the purpose of teaching.

> *"I continued to use this same approach for teaching photosynthesis involving problem solving and a socio-scientific issue, because I appreciated that it helped to motivate students to learn. It provided a better understanding of the world and the place of humans in nature."*
>
> (Extended to include future considerations - Comment by teacher T8)

Examples for the dimension "Student motivation", describing how teachers motivated students to learn. Following the 3-stage model, the science learning was initiated by a familiar contextual frame of reference, linked to a need in the eyes of students, stemming from a social context involving science. All teachers indicated that they considered motivation important. But while the contextual introduction in each teaching module (stage 1) was expected to be promoted as motivational for students, the teachers reported that they motivated students in different ways.-

Associated with category (a) - teacher used scientific questions as a way of motivating students. Teachers used science questions related to familiar situations so as to motivate students to learn. The scientific problem was seen as important, rather than paying attention to the economic impact e.g. metal corrosion on society, or how metal corrosion affected a person's daily life in the case of rusting of cars.

> *'Why do metals rust?'*
>
> (Comment by teacher T5)

A further example associated with category (a) - teacher employed a new teaching/learning method to motivate students.

> *'I asked the students to make a video about the effects of alcohol on people. The students had never made a video before and it was interesting for them and motivated them to look for information and learn.' (Comment by teacher T9)*

Associated with either category (a or b, but not by category c) – teacher used questions related to everyday life. Teachers emphasised linking the teaching to everyday life, overlooking more general aspects such as the impact on the society.

> *'Why should we know about insects? Is anyone amongst you allergic towards wasp stings? What do you do when a wasp stings you?'*
>
> (Comment by teacher T10)
>
> *'Why is it not beneficial to eat potato chips?'*
>
> *(Comment by teacher T2)*

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Associated with either category (b or c, but not a) - motivation via a relevant socio-scientific issue. Teachers used a socio-scientific issue, which was closely linked to the economy, the culture and/or the society.

> *'Can driving when tired be a crime re- reaction time? We were watching an animation of how tiredness influences reaction time to stop the car and how a tired driver is creating a danger for himself, as well as other drivers and passengers.'*
>
> (Comment by teacher T7)

> *'You become a landowner and what plants can you grow and why? This topic was related to the Estonian economy, rural employment, soil chemistry, agriculture, plant growth conditions, etc.'*
>
> Comment by teacher T3)

Examples for the Dimension "Inquiry activities", describing purposes for utilising inquiry activities. Within the 3-stage model, this related to the de-contextualised 2nd stage, where scientific learning paid attention to the nature of science and the important role of undertaking scientific inquiry activities. The teachers tended to report they used inquiry activities for three purposes:

a) Make learning attractive and interesting;
b) Better conceptualising the science ideas, and
c) Better conceptualising the science ideas and their interrelationship with socio-scientific issues within the society.

Associated with category (a) – inquiry activities which promote interest. While all teachers emphasised that inquiry activities make learning more interesting and attractive to students, responses by teachers associated with category saw this aspect as the major purpose.

> *'I used inquiry activities for making the teaching more attractive. Students like to do experiments.'* (Comment by teacher T5)

Associated with category (b) - emphasising inquiry activities aid understanding of the subject matter.

> *'Experimental work helped students to better understand how to protect metals from rust and also the chemistry conceptualisation of metal corrosion'.*
>
> (Comment by teacher T7)

Associated with category (b or c, but not by a) – interconnecting the science with the society. Teachers contributed to the understanding of the nature of science by developing students' problem-solving and higher order thinking skills, but also went further to promote the interrelationship with socio-scientific issues within society.

> *'I used inquiry activities so that students could solve problems and develop problem-solving skills; it aided understanding of science ideas (concepts). Also, in the worksheet, I included questions on how this problem was connected to everyday life and the society.'*
>
> (Comment by teacher T2)

> *'Inquiry learning allows chemistry to link with economics and the surrounding environment e.g. you becoming a landowner is a good example where students need to consider economic aspects as well environmental aspects and be able to link with knowledge from Chemistry and Biology in order to get an income from owning land.'*
>
> (Comment by teacher T3)

Examples for the Dimension "Decision making", describing how decision-making is perceived**.**

Decision-making referred to the re-contextualisation stage 3 in the model, involving consolidation of the scientific learning through transference to the initial contextual frame and involving justified socio-scientific decision-making. For this, teachers reported four different approaches to decision-making.

Associated with category (a) - no decision making involved. Decision-making was not recognised; students

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simply summarised their work.

> *'Student summarised how alcohol affects the human body.'*
>
> (Comment by teacher T9)

Also associated with category (a) – basing decisions on science content. The student solved science problem and then decisions were made, based on the laboratory findings i.e. focusing on the science content.

> *'Students reported the results of their experiments and found the best way to protect the metals from rusting.'*
>
> (Comment by teacher T5)

Associated with category (a or b) - decision made based on problems in everyday life. Decision made based on problems what related to issues arising from everyday life.

> *'Finally, we discussed the toxicity of berries and animals in Estonia and how to protect ourselves from them.'*
>
> (Comment by teacher T10)

> *'We were discussing which kind of problems might appear for parents of students 15 - 18 years old and where to seek help.'*
>
> (Comment by teacher T1)

Associated with category (c, but not a or b) – relating the science to society. The teachers used a socio-scientific decision-making procedure. The science problem was linked with social issues and students provided evidence for different resolutions to the issue and then, between them, made a justified, consensus decision.

> *'In conclusion, we discussed what is healthy eating and what the consequences of obesity are for human health and for the country as a whole, and what to do to reduce overweight in society. Overweight is an issue at a local, national and global level.'*
>
> (Comment by teacher T8)

Examples for the Dimension "Purpose of teaching", describing thoughts on the purpose of teaching.

Education through science focused on students' educational gains and stressed the learning to be acquired through science lessons. Both cognitive knowledge and process skills were intended as important parts of the intellectual development of students. In addition, science, personal and social skills associated with the development of the person were included, involving social values and interpersonal relations**.** The teacher's responses were grouped as:

1. Curriculum implementation with respect to promoting science content, or
2. Developing general/generic skills, or
3. Developing a wide range of skills oriented to include social and value judgements.

Associated with category (a) - purpose of teaching is curriculum implementation; subject content dominant, but also including cross-curricula themes. Such teachers considered it important to complete the curriculum. Very little attention was paid to developing students' skills (problem-solving, communication, cooperation skills, even though these were also mentioned in the curriculum).

'It is my duty to promote the curriculum. The curriculum is extensive, and there is little time for any one topic. My task is for the students to achieve the learning outcomes and to pass in the examination. I want the students to gain a good grasp of the subject knowledge and skills.'

(Comment by teacher T5)

Associated with category (b, but not a) – develop generic skills. Alongside knowledge, teachers noted that their role was to develop generic skills (problem solving, decision-making, cooperation, communication, and time management skills).

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'Besides teaching the subject, it is important that students learn to manage their time and set goals.' (Comment by teacher T4)

'Group work requires student's responsibility; otherwise you will not be able to get cooperation. Again, and again, it arose that someone had failed to do his or her job. As a teacher, you have to take this into account.'

(Comment by teacher T7)

Associated with category (c, but not a or b) - also the need to develop value judgements. Besides the acquisition of knowledge and skills, the teachers saw the need to promote value judgements (the development of a responsible citizenship) and saw lifelong learning as important.

'It was important to me that my students were able to cope in life and respect other people and nature.' (Comment by teacher T8)

'My goal was to promote essential skills for their life among students and get them to behave as responsible citizens. Schools must prepare students to lead an independent life so as they can be satisfied with their lives and useful for the society.'

(Comment by teacher T1)

Determining the Category of Teacher Ownership

Based on the descriptions put forward by teachers with respect to the category assigned per dimension, paying careful consideration to the degree of category description overlap for dimension 2-5, the 10 teachers were identified with the categories for each dimension of variation as indicated in table 2. The overall teacher ownership was established by careful consideration of the importance of different dimensions and the very distinct categorisation identified for the reflection type dimension. The discussion section further clarified the categorisation for teachers 1,2,4,5, 6 and 10.

Table 2
Identifying Teacher Ownership, based on the teacher categories identified per dimension (N=10)

Dimension	Teachers identifying with category (a)	Teachers identifying with category (b)	Teachers identifying with category (c)
1.Reflection type	T5.T9.T10	T1.T2.T4.T6.T7	T3.T8
2.Student motivation	T4.T6.T9.T10	T5.T7	T1.T2.T3.T8
3.Inquiry activities	T5.T9.T10	T2.T4.T6.T7	T1.T3.T8
4.Student decision making	T4.T5.T6.T9	T1.T2.T7.T10	T3.T8
5.Purpose of teaching	T5.T9.T10	T2.T4.T6.T7	T1.T3.T8
Overall teacher ownership category	T5.T9.T10	T1.T2.T4.T6.T7	T3.T8

Discussion

This study sought to identify the categories of sustainable teacher ownership related to a MCST approach (Valdmann et al., 2016). The identification took place 3 years after teachers had previously been involved in a longitudinal CPD intervention and these had the opportunity to subsequently develop and reflect on their teaching in their own way.

The study showed that the teachers exhibited their ownership in different ways. A major indicator in distin-

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guishing between the formats of the teaching exhibited by the teachers was found to be the manner in which the teachers were able to reflect on their teaching. Teacher self-reflection was thus identified as an important dimension to consider when wishing to appreciate the teacher's practices and beliefs. While all teachers were able to reflect on the effectiveness of their teaching, less were able to focus on solutions for problems encountered and fewer still on reflecting on future considerations. As Wenger (2005) contended, reflection helped teachers to focus on the complexity of interactively relating between practice and theory.

When reflecting, all teachers emphasised emotional aspects, indicating how happy or unhappy they were when implementing the MCST approach. The teachers were able to reflect on aspects of the teaching that went well, or badly and were able to clearly articulate problems. The reflections showed teacher recognised inconsistencies between the espoused 3-stage model (Holbrook & Rannikmäe, 2017) and what was actually undertaken in the classroom.

Additional questions, where appropriate, were asked during the semi-structured interviews to determine further aspects of variations, predicted to play a meaningful role in describing categories of teacher ownership. These questions related to the manner in which the teachers established student motivation, included inquiry-based teaching, involved students in decision-making and indicated the purpose of science teaching. All aspects of variations were found to play a role in framing the operationalisation of the science teaching and gave indications of differences in conceptualisation. In the most sophisticated responses, teacher beliefs were seen as associated with the inclusion of socio-science issues for student motivation (Sadler & Zeidler, 2005; Zeidler et al., 2005), determining ways for stimulating the need for conceptual science learning (Jho et al., 2014; Klosterman & Sadler, 2010) and also undertaking justified socio-scientific decision-making (Acar et al., 2010; Levinson, 2006).

Differences were detected between teacher responses, when teachers were triggered to comment on student motivation. Although differences were identified related to the emphasis on subject matter, or to everyday life, teachers relatively rarely associated this with focusing on the initial motivational part of teaching, or on putting forward a socio-scientific issue involving the subject matter (Holbrook & Rannikmäe, 2017). While all teachers commented on the use of inquiry teaching (Anderson, 2002; Furtak et al., 2012), opinions varied as to whether it was an interesting way of teaching or having importance for the engaging of students in problem solving. Only a few teachers indicated a link between inquiry-based teaching and forming a base for follow-up socio-scientific discussions (Holbrook & Rannikmäe, 2017). In fact, few teachers appreciated the learning value in including socio-scientific decision-making activities in their teaching (Sadler & Zeidler, 2005; Zeidler et al., 2005). All teachers easily recognised the purpose of the MCST approach as promoting science conceptual learning (Holbrook & Rannikmäe, 2007), but only half of the teachers stated the reasons for MCST teaching was to also develop self-regulatory skills (e.g. self-control, dependability, adaptability, optimism). Only two teachers went further and indicated the purpose of teaching was to promote lifelong learning (EC, 2019), or to become a responsible citizen (EU, 2019) and thus saw the need to include a wide range of science-related skills, plus orient their teaching to take account of social values in making socio-scientific judgements (Sadler & Zeidler, 2005; Zeidler et al., 2005).

Through undertaking phenomenographic analysis (Akerlind, 2012; Marton & Booth, 1997), this study showed the different categories of MCST ownership exhibited by the teachers. Primarily, the category came mainly from their reflections, where the categories identified directly corresponded to the overall teacher ownership category. Nevertheless, the categories for the other dimensions of variation added clarity. For example, teacher T1 responses were strongly associated with category 'c' for the dimensions - motivation, inquiry activities and purpose of teaching, but reflections were heavily associated with dealing with scientific problems so much so that perceptions of decision making were poorly related to the MCST expectations. Teacher T2 identified with the descriptions for category 'b', although having a strong belief in the need for motivating student. Teachers T4 and T6 did not see the need to recognise a social component for MSCT science teaching, other than for motivation purposes, while T5 and T10 indicated relatively little appreciation of MCST teaching.

The three teacher ownership categories were meaningfully described as 'emotional' (labelled as (a) in Table 1 and exhibited by 30% of the teachers), 'experiential' (labelled as (b)', relating to 50% the teachers), and 'paradigmatic' (labelled as (c), relating to 20% of the teachers) as described below:

a) Emotional teachers (T5, T9, T10) were very much related to the conceptual knowledge and skills as the overwhelming focus, neglecting personal and social development. Emotional ownership described a feeling, or sense of ownership, which appropriately portrays operational elements of the MCST model, but which was

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not really being interpreted as per the intended philosophy and approaches. Emotional ownership teachers recognised the 3-stages in the MCST approach, but saw them as separate components (i.e. motivational, inquiry-based science learning, and decision-making). These teachers informed others about the effectiveness of their teaching through teacher success in promoting the subject (main emphasis being science cognition). They did not really pay attention to reflecting on students' gains with respect to attitudes and values (re-moral, ethical, environmental, economic, social, etc.) (Eurydice, 2011; NRC, 2010; OECD, 2016).

b) Experiential teachers (T1, T2, T4, T6, T7) found the socio-scientific frame difficult to handle. Experiential ownership referred to teachers who possessed the ability to use the intended approach, as per a socio-scientific motivational introduction so as to establish prior science learning and to facilitate an appropriate baseline for the promotion of conceptual science learning in the 2nd stage of the MCST approach (Valdmann et al., 2016). They also possess the ability to further guide students to apply, meaningfully, their newly gained science within an everyday, or societal decision-making, situation. During reflection, these teachers were able to identify problems and respond to the questions about the theory, practice, assumptions, beliefs and values related to teaching (Posnanski, 2002; Ryan & Deci, 2000). They were also able to reflect on student – teacher interactions, emphasising teacher actions, but they did not pay attention to the value of the overall learning. Experiential ownership teachers used the MCST model in a rather narrow, compartmentalised way (i.e. how to motivate students, how to apply IBL - inquiry based learning, or how to teach students to make a decision, based on evidence). The term 'experiential' was chosen, because their 'sense of ownership' (Blonder et al., 2008; Ketelaar et al., 2012; Kyza & Georgiou, 2014; Saunders et al., 2017) of the teaching approach was based on their experience in using MCST (Valdmann et al., 2016).

c) Paradigmatic teachers (T3, T8) identified strongly with the purpose of education with respect to the three attributes (learn to learn; lifelong learning; becoming a responsible citizen) (EC, 2019; NRC, 2010; Osborne & Dillon, 2008). These teachers described the desired ownership of the 'education through science' (EtS) philosophy (Holbrook & Rannikmäe, 2007) and the intended operationalisation of a context-based approach (Gilbert et al., 2011) as per the MCST approach (Valdmann et al., 2016). They indicated the sustainable, paradigmatic shift intended. A teacher, who exhibited paradigmatic ownership, orientated their reflexive responses to give attention to considering future developments rather than simply relating to the identification of, and how to deal with, problems encountered. Paradigmatic described full acceptance of a shift to ownership of the EtS philosophy (Holbrook & Rannikmäe, 2007).

The different categories of sustainable teacher ownership were seen as hierarchical. The paradigmatic ownership teachers recognised that the MCST approach (Valdmann et al., 2016) provided the opportunity to integrate relevance and student motivation as key factors in enhancing scientific conceptualisations, and that the re-contextualised, 3rd stage provided an opportunity to consolidate the science learning as well as develop decision making skills in a socio-scientific, argumentation frame. Experiential and emotional teachers, while identifying the 3rd stage by name, had difficulty in appreciating the value of this stage as a key learning element. In fact, emotional ownership teachers tended to see the strength of the MCST approach overwhelmingly in terms of enhancing conceptual science learning.

These categories of sustainable ownership seem to be unique in comparison with findings by other researchers. An earlier study by Rannikmäe (2001) identifies three categories of teacher ownership, in this case towards scientific and technological literacy (STL) teaching. In that study, the categories are labelled as – 'subject learning activity based', 'sequenced activity based', and 'social issue based'. The social issue based category can be identified with the dimension geared to decision making, positively supported by the paradigmatic category of ownership, but the intended teacher ownership is more strongly detected through considering teacher reflections on possible future actions, rather than issues arising from the society at the local, national and global level. The 'sequenced activity based' category has strong similarities to the experiential category label put forward in this research, while 'subject learning activity based' is strongly focused on ownership of cognitive science, primarily associated with the emotional category, as described here.

In this paper, it is argued that between the 'sense of ownership' (Blonder et al., 2008; Ketelaar et al., 2012; Kyza & Georgiou, 2014; Saunders et al., 2017) and the identification of a paradigmatic change in 'sustainable teacher ownership', stages of 'towards ownership' categories (Hofstein et al., 2012) can be considered. This can build on the self-efficacy stage established following the initial CPD, through seeking to internalise the teach-

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ing/learning as intended through operationalising the 3-stage model using the MCST approach (Valdmann et al., 2016), as well as meaningfully portraying the intended philosophy and approach to others. This is thus seen as an additional dimension beyond a self-vision of one's own capability. It indicates that just because a teacher has high levels of self–efficacy (Bandura, 1977), it does not mean the teacher goes beyond this self-perception to reach a sustainable ownership stage i.e. the stage where others can compare the intention and actual vision and where the teacher makes such ideas their own, based on the intended philosophy. The paradigmatic ownership stage of the innovation is suggested as the real target of any CPD programme, when the philosophy being promoted by a provider or the system and that by the teacher, conceptually being able to absorb and promote to others, becomes one and the same. This suggests that undertaking a CPD programme by itself is not enough; further post CPD consolidation aspects are needed.

It is clear that CPD providers need to be at the paradigmatic ownership stage, possessing a view of teaching that sees the goals of education beyond content acquisition, can be expected to encourage teachers to value students being capable of self-learning (Ryan & Deci, 2000) and appreciate the inclusion of social and/or value judgements as an integral part of science education. A danger, if CPD providers are at the emotional, or experiential categories, is that the vision of subject content within science education is likely to be over emphasised, with student involvement, in facilitating their own learning, appreciated only to the extent that it is not too time-consuming.

Conclusions and Implications

This study shows that gaining self- efficacy, or a sense of ownership, to express the intentions from a CPD programme is not sufficient for preparing teachers for taking ownership in implementing new developments. By seeking teacher reflections on the implementation of their own teaching, professed to be in line with a prior CPD programme, this study shows ownership is more about motivationally promoting subject matter, in this case in science teaching, and that teacher reflections need to go beyond addressing student concerns and they need to examine the totality of the learning being portrayed, in this case, on the motivational, context-based approach associated with students' personal, cognitive and societal interactions.

In general, teacher ownership is not to be taken as the same as teacher self-efficacy. While all teachers in this study established self-efficacy through an earlier CPD and appreciate the MSCT approach in their teaching, this study shows that the way teachers express ownership, determined through examining meaningful indicators based on a phenemonographic analysis, substantially differ. The attributes of MCST are promoted through differing in-depth levels, described as emotional, experiential and paradigmatic depending on the presence of social interaction and the strengths of student involvement in socio-scientific argumentation, based on sound scientific cognition.

The findings suggest that ownership, when simply applied at the CPD level, is associated, at best, with a 'sense of ownership' as an alternative way to express self-efficacy, based on Bandura's indicators of confidence and competence in using a new teaching approach (Bandura, 1977). Teacher ownership can be identified at different levels when determined in the actual teaching environment, associated with the degree of consideration of factors on which to reflect. The characteristics of sustainable, paradigmatic or experiential or emotional ownership are shown to go beyond everyday science conceptual learning settings and, especially at the paradigmatic level, value the involvement of students in inter-relating the science with motivational and social aspects in a justified manner.

In this study, the science teachers who reached sustainable, paradigmatic ownership show, particularly through the width of reflection on their teaching, that they fully appreciate the attributes of the 'education through science' philosophy and the operationalisation of the 3-stage model, utilising a motivational, context-based approach. On the other hand, the science teachers exhibiting ownership categories at the experiential and emotional categories, tend to indicate teaching based on more superficial characteristics with reflection limited to cognition aspects.

A potential implementation from this study is that involving teachers in CDP programmes is insufficient for teachers to gain sustainable paradigmatic ownership of that intended. It suggests further follow-up interventions are needed to consolidate the ideas emanating from any CPD. The desired sustainable, paradigmatic teacher ownership needs to be appreciated as a teaching requirement and needs to be the major focus for post-CPD considerations.

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Limitations of the Study

The study had limitations, based on the comparatively small sample size of voluntary teachers involved in the CPD, who could not, necessarily, be taken as representatives of the teachers' involved in the earlier CPD programme. These teachers were motivated to participate in the interview and willing to promote MCST in their classroom and were willing to reorganise their teaching programme to accommodate this. Even so, the percentage of these volunteering teachers meeting the expectation of full ownership was low (20%) and points to the difficulty in promoting a sustainable change in teachers.

Establishing categories of teacher operations in the classroom based on semi-structured interviews, lasting approximately 1 hour, limited the extent to which teachers were guided to promote the teaching intentions being practiced in the classroom. This led to limitations in establishing coverage of the teaching emphases and the manner in which the philosophical ideas are being implemented.

References

Acar, O., Turkmen, L., & Roychoudhury, A. (2010). Student difficulties in socio-scientific argumentation and decision-making research findings: Crossing the borders of two research lines. *International Journal of Science Education*, *32*(9), 1191-1206. https://doi.org/10.1080/09500690902991805

Akerlind, G. (2012). Variation and commonality in phenomenographic research methods. *Higher Education Research and Development, 31*(1), 115-127. https://doi.org/10.1080/07294360.2011.642845

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, *13*(1), 1-12. https://doi.org/10.1023/A:1015171124982

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review, 84*(2), 191-215. https://doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (1997). The nature and structure of self-efficacy. *Self-efficacy: the exercise of control* (pp. 37-78). WH Freeman and Company.

Blonder, R., Kipnis, M., Mamlok-Naaman, R., & Hofstein, A. (2008). Increasing science teachers' ownership through the adaptation of the PARSEL modules: A 'Bottom-up' approach. *Science Education International, 19*(3), 285–301.

Cope, C. (2004). Ensuring validity and reliability in phenomenographic research using the analytical framework of a structure of awareness. *Qualitative Research Journal*, *4*(2), 5-18.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development.* Learning Policy Institute.

Deci, E, L. (2009). Large-scale school reform as viewed from the self-determination theory perspective. *Theory of Research in Education*, *7*(2), 244-252. https://doi.org/10.1177/1477878509104329

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181-199. https://doi.org/10.1177/1477878509104329

EC (2019). *Key competences for lifelong learning.* https://op.europa.eu/en/publication-detail/-/publication/297a33c8-a1f3-11e9-9d01-01aa75ed71a1/language-en

EU (2019). *Citizenship education in Europe.* https://ec.europa.eu/citizenship/pdf/citizenship_education_in_europe_en.pdf

Eurydice (2011). *Science Education in Europe: National Policies, Practices and Research.* Brussels: EURYDICE.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D., C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3*),* 300-329. https://doi.org/10.3102/0034654312457206

Gilbert, J. K., Bulte, A. M., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education*, *33*(6), 817-837. https://doi.org/10.1080/09500693.2010.493185

Hofstein, A., Katchevich, D., & Mamlok-Naaman, R. (2012). Teachers Ownership: What is it and how it is developed? In: C. Bolte, J. Holbrook, F. Rauch. (Eds.). *Inquiry-based Science Education in Europe: Reflections from the PROFILES Project* (pp. 56-58). Freie Universität Berlin.

Holbrook, J., & Rannikmäe, M. (2007). Nature of science education for enhancing scientific literacy. *International Journal of Science Education, 29*(11), 1347-1362.

Holbrook, J., & Rannikmäe, M. (2010). Contextualisation, de-contextualisation, recontextualization–A science teaching approach to enhance meaningful learning for scientific literacy. .In I. Eilks & B. Ralle (Eds.). *Contemporary Science Education* (pp. 69-82). Shaker Verlag.

Holbrook, J., & Rannikmäe, M. (2017). Motivational Science teaching using a Context- based Approach. In: B. Akpan, (Eds.). *Science Education: A Global Perspective* (pp. 189–217). Springer International Publishing. https://doi.org/10.1007/978-3-319-32351-0_10

Holbrook, J., Rannikmäe, M., & Valdmann, A. (2014). Identifying teacher needs for promoting education through science as a paradigm shift in science education. *Science Education International*, *25*(2), 4-42.

https://doi.org/10.33225/jbse/20.19.659

Howe, A. C., & Stubbs, H. S. (1997). Empowering science teachers: A model for professional development. *Journal of Science Teacher Education*, *8*(3), 167-182. https://doi.org/10.1023/A:1009487417488

Jho, H., Yoon, H. G., & Kim, M. (2014). The relationship of science knowledge, attitude and decision making on socio-scientific issues: The case study of students' debates on a nuclear power plant in Korea. *Science & Education, 23*(5)*,* 1131-1151. https://doi.org/10.1007/s11191-013-9652-z

Ketelaar, E., Beijaard, D., Boshuizen, H. P. A., & Den Brok, P. J. (2012). Teachers' positioning towards an educational innovation in the light of ownership, sense-making and agency. *Teaching and Teacher Education, 28*(2), 273–282. https://doi.org/10.1016/j.tate.2011.10.004

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socio-scientific issues-based instruction. *International Journal of Science Education, 32*(8), 1017-1043. https://doi.org/10.1080/09500690902894512

Kyza, E., & Georgiou, Y. (2014). Developing in-service science teachers' ownership of the pedagogical framework through a technology-supported participatory design approach to professional development. *Science Education International, 25*(2), 57–77.

Levinson, R. (2006). Towards a theoretical framework for teaching controversial socio-scientific issues. *International Journal of Science Education*, *28*(10), 1201-1224. https://doi.org/10.1080/09500690600560753

Marton, F., & Booth, S. A. (1997). *Learning and awareness.* Psychology Press.

National Research Council (NRC). (2010). *Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary*. Margaret Hilton, Rapporteur. Board on Science Education, Centre for Education, Division of Behavioural and Social Sciences and Education. The National Academies Press.

OECD (2016). *PISA 2015 results: Excellence and equity in education* (Vol.1). OECD Publishing

Ogborn, J. (2002). Ownership and transformation: Teachers using curriculum innovations. *Physics Education, 37*(2),142-146. https://doi.org/10.1088/0031-9120/37/2/307

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol.3). The Nuffield Foundation.

Pierce, J. L., Kostova, T., & Dirks, K. T. (2003). The state of psychological ownership: Integrating and extending a century of research. *Review of General Psychology, 7*(1)*,* 84-107. https://doi.org/10.1037/1089-2680.7.1.84

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education, 13*(3), 189-220. https://doi.org/10.1023/A:1016517100186

Rannikmäe, M. (2001). *Operationalisation of Scientific and Technological Literacy in the Teaching of Science* PhD thesis. University of Tartu.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. https://doi.org/10.1037/0003-066X.55.1.68

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socio-scientific decision making. *Journal of Research in Science Teaching, 42*(1)*,* 112-138. https://doi.org/10.1002/tea.20042

Saunders, M., Alcantara, V., Cervantes, L., Del Razo, J., López, R., & Perez, W. (2017). *Getting to Teacher Ownership: How Schools Are Creating Meaningful Change.* Brown University, Annenberg Institute for School Reform.

Valdmann, A., Rannikmäe, M., & Holbrook, J. (2016). Determining the effectiveness of a CPD programme for enhancing science teachers' self-efficacy towards motivational context-based teaching. *Journal of Baltic Science Education, 15*(3)*,* 284–297.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Wenger, E. (2005). *Communities of practice: Learning, meaning, and identity* (13th Ed.). Cambridge University Press.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socio-scientific issues education. *Science Education, 89*(3)*,* 357-377. https://doi.org/10.1002/sce.20048

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Appendix 1. Background Information for the teachers and the identified ownership level, 3 years after the CPD provided to promote MCST.

Teacher	Science Subjects taught	School type	Ownership level attained
T1	Chemistry, Health	Countryside High School	Experiential (b)
T2	Chemistry	City High School	Experiential (b)
T3	Chemistry, Agronomy	City High School	Paradigmatic (c)
T4	Science, Biology	Countryside Middle School	Experiential (b)
T5	Chemistry	Countryside High School	Emotional (a)
T6	Science, Physics	Countryside Middle School	Experiential (b)
T7	Chemistry	Countryside High School	Experiential (b)
T8	Science, Biology, Chemistry	Countryside Middle School	Paradigmatic (c)
T9	Biology	City High School	Emotional (a)
T10	Biology	Countryside Middle School	Emotional (a)

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