Secondary Science Teachers as Curriculum Makers: Mapping and Designing Scotland's New Curriculum for Excellence

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Abstract

Scotland is one of several countries to have recently implemented a new national curriculum to highlight 21st century educational priorities. Teachers have been mandated to follow the new curriculum guidelines, known as Curriculum for Excellence (CfE), since the fall of 2010. The purpose of this study was to use a phenomenological lens to investigate how Scottish secondary science teachers are experiencing their work of curriculum development, including daily lesson design and more broadly, curriculum mapping within the context of reform (Remillard, 1999). We probed seven science teachers' experiences to create both a composite profile of conscious thoughts about curriculum design and individual profiles that highlight interactions between the curriculum mandates, beliefs and agentic orientations. The study indicated that changes to curriculum development required accepting new cognitive commitments including: (a) analyzing the CfE document to discern the most significant principles underlying change; (b) reflecting on the ways that science teacher curriculum development is a problem-solving endeavor; (c) undertaking the complex processes of curriculum mapping, from primary school all the way through national qualification exams; and (d) recognizing that the epistemological frame for students' science learning has changed and providing opportunities for students to create and apply knowledge. Two significant findings include the unpacking of these cognitive activities as part of a transformation toward a new epistemology of pedagogy, and the assertion that official curriculum documents can promote change, albeit with caveats concerning individual beliefs, agentic orientations and possibilities for agency within school contexts.

Key words: teacher change, teacher beliefs, curriculum development.

It has been acknowledged for decades that teachers are intelligent decision makers who interpret and modify the official curriculum in accordance with what they believe are the needs of their students (Cuban, 1998; Munby, 1984; Richardson, 1996). In this sense, teachers play a crucial role as curriculum creators (Priestley, Edwards, Priestly & Miller, 2012; Shawer, 2010). They have the ultimate responsibility for translating curriculum documents produced by government or policy entities into teachable forms for the classroom. Research has shown that teachers modify curriculum to align with their own moral and educational beliefs (Bryan, 2012; Kelly, 1999; van Driel, Beijaard & Verloop, 2001). Teachers' interpretations of the official curriculum can vary widely and in some cases diverge significantly from the intentions of the curriculum designers (Spillane, 2002; Supovitz, 2008). Scholars often refer to these different forms of the curriculum as the "planned and the enacted curriculum" or the "intended and implemented curriculum" (Kelly, 1999, p. 11, Clandinin & Connelly, 1992). Kelly referred to the "make or break" role of teachers in implementing curriculum reform in the following way:

> Teachers have been known to sabotage attempts at change; certainly it is clear that such change can succeed only when teachers concerned are committed to them, and, especially, when they understand, as well as accept their underlying principles (Kelly, 1999, pgs. 14-15).

These axioms apply to science teaching and manifest additional force when teachers are required to implement externally mandated curriculum reform. Core beliefs about the purposes of teaching science, the school science curriculum, the nature of students and what counts as good science teaching have repeatedly been shown to act as filters that science teachers apply to the intended curriculum (Bryan, 2012; Munby, 1984; van Driel et al., 2001; Wallace, 2014). Moreover, teacher agency, or the concept of teachers achieving their own aims in congruence with their beliefs is dependent on the ecology of the environment in which they work and the way interpretations of the new curriculum have trickled down to the classroom (Hume & Coll, 2010).

Since 2004, Scotland has been developing a major curriculum reform initiative, Curriculum for Excellence (CfE). The CfE development process has involved high levels of participation by stakeholders, most specifically teachers. The curriculum includes achievement objectives, learning experiences and valued skills and attributes of students (Education Scotland, undated). Since 2010, teachers in Scotland have been officially required to use CfE as the basis for classroom practice. How science teachers are responding to this challenge is an important topic for educational research, since CfE represents one of several new international curricula based on 21st century skills (Sinnema & Aitken, 2013). Internationally, some curriculum designs place more emphasis on performance outcomes for mastering content and skills, leaving the "how" up to the teachers, while others place more emphasis on suggested teaching methods (e. g. inquiry), leaving the particulars of content and performance up to the teachers (Achive.Inc., undated; New Zealand Ministry, undated; Sinnema & Aitken, 2013). Authors of Scotland's CfE have taken a centrist approach with some direction for content elements and teaching approaches specified, yet still leaving many of the details up to teachers (Humes, 2013; see sample curriculum objective, Appendix A, Education Scotland, undated).

The purpose of this study was to investigate how Scottish science teachers are responding to the challenge of designing classroom instruction within the context of centrally mandated curriculum innovation. We focused on science curriculum development by teachers in the

Scottish context for a number of reasons. First, the new curriculum was purposefully designed to be less prescriptive, so that teachers could practice more professional autonomy when making decisions about pedagogy and content (Priestley, Biesta & Robinson, 2015) in contrast to the narrow learning objectives of the previous national curriculum. Therefore, the case of Scotland affords an opportunity to observe how teachers are responding to curriculum documentation that provides less hierarchical direction and presumably allows more choice.

Second, science teaching in Scotland, up until recently, has followed a fairly traditional model, at variance with developments in constructivist science elsewhere. CfE thus requires a considerable shift from what might be termed transmissionist, content-driven teaching towards constructivist modes of pedagogical practice (Priestley, 2011; Humes, 2013). Researchers have indicated that such a shift requires, not only changes in practice, but also changes in the epistemological and pedagogical beliefs of teachers (Sahlberg, 2011a; 2011b; Trumbell, Scarano & Bonney, 2006; van Driel et al., 2001; Yerrick, Parke & Nugent, 1997). Third, and drawing together the above two points, curriculum change of this nature requires high degrees of teacher agency. We follow an ecological view of teacher agency (Priestley, Biesta & Robinson, 2015) and explore these issues in more detail in ensuing sections of the paper.

The research draws upon phenomenology, the study of human experience, as a theoretical and methodological perspective to examine Scottish science teachers' conscious thoughts about their experiences as curriculum makers in response to mandated curriculum reform with CfE. We asked the following research questions:

- What do Scottish secondary science teachers interpret as being the most significant innovations in the CfE that impact their work as curriculum developers?
- How has the composite experience of what it means to be a science teacher curriculum developer shifted with the advent of the CfE as the mandated curriculum?

- How do individual teachers experience curriculum development with CfE in conjunction with their core science teaching beliefs and agentic orientations?

Nature of and perspectives on the Scottish Curriculum for Excellence

Traditionally, the hierarchical nature of schooling in Scotland meant that mainstream teachers had not been overly concerned with curriculum development prior to about 2001. Principal (lead) teachers usually took on the role for departments and, due to the tightly prescribed nature of previous curriculum standards, the task mainly consisted of fitting of subjects into timetabling columns, rather than a meaningful process of developing practices to fit with curricular purposes (Priestley, 2013). Consequently, schools tended to be fairly conservative in their approaches to curriculum development, and teachers had tended to teach from a narrow range of curriculum materials typified by lectures, workbooks and verification labs. The content of teaching was also been driven by examinations syllabi in the 4th, 5th and 6th years of secondary schooling (Raffe, 2008).

Since the early 2000s, a number of Scottish policy documents have increasingly called for classroom teachers to take on a greater role as curriculum designers. These included: (a) a report produced by a team from the European Organization of Economic Cooperation and Development (OECD, Raffe, 2008) that recommended more policy consultation with teachers about pedagogic and curricular design; (b) the McCrone Agreement (Scottish Government, 2001) that explicitly gave teachers the responsibility for curriculum development; (c) a white paper called, “Teaching Scotland’s Future” (Donaldson, 2011) that established guidelines for teacher involvement in all aspects of education and provided for partnerships with universities for school improvement; and (d) new professional standards for teaching (General Teaching Council, 2016) that included higher expectations for teacher learning and curriculum development. Increased professional development in technology, induction year development for beginning teachers, and funding for advanced degrees were three vehicles through which teacher professional knowledge was fostered.

Thus, a number of initiatives, websites, partnerships and professional development opportunities were developed, as well as changes to professional discourse (for example, encouraging action research), to promote the idea of teacher empowerment and responsibility for curriculum development in parallel with the implementation of CfE. Specific professional development on ways to implement CfE has also occurred, although it's frequency and quality has varied across local authorities (Ian Menzies, personal communication, 05/13/2015). The conception of teacher as curriculum developer is therefore relatively new in Scottish schools, especially for veteran teachers, having been promoted strongly over about the last five years (Humes, 2013). It is against this backdrop that we explore teacher curriculum development for secondary science in the current study.

Early formulations of CfE acknowledged the importance of the following features to Scottish educators: (a) making learning engaging and challenging; (b) producing seamlessness across ages 3-18; (c) not being over crowded in content; (d) giving students some opportunity for personal choice; and (d) using assessment to support learning (Scottish Executive, 2004). The initial publication set out descriptions of four sets of key competencies, known as the Four Capacities: successful learners; confident individuals; responsible citizens and effective contributors. Between 2004 and national implementation in 2010, these formulations were fleshed out in a variety of documents. These documents included the publication of key learning outcomes or objectives- the "Experiences and Outcomes"- for students, framed as "I can" statements and set out as linear levels in each subject domain (see sample curriculum objective in Appendix A; Education Scotland, undated; Humes, 2013).

One key characteristic of CfE is that the language of the learning objectives and experiences is relatively vague and broad in comparison to the previous national curriculum (Humes, 2013; Priestley, 2013). As mentioned above, this was a deliberate choice on the part of the curriculum designers who sought to give teachers more autonomy to shape their teaching. Teachers were now were given a much larger degree of freedom to develop site-based lessons, units, and themes. However, in many cases these early aspirations have been eroded: teachers have been reluctant to accept this new level of responsibility in the face of persisting systems for teacher accountability through inspections and usage of attainment data, which highlighted the risk of innovation for many teachers (Priestley, 2013).

Two further developments have contributed to the uncertainty in the context for change. First, the late redevelopment of national qualifications (accreditations necessary for university and work) in the senior phase of secondary, although redesigned to fit the new curriculum, has further reinforced the tendency for qualifications to drive curriculum and has added to assessment demands and associated bureaucracy for teachers and students (British Broad Casting, 2014). Second, the recent announcement that standardized assessments will be developed to provide system data about individual achievement and the performance of schools has created much anxiety in the teaching profession about increased achievement demands (NASUWT, 2015; for details of the new approach see, Scottish Government, 2015). These accountability factors have certainly affected the teachers' experience of curriculum development as it will be described below. [1]

Theoretical frameworks

We chose Remillard's (1999) model of *teacher as curriculum developer* as a key construct for our investigation into science teachers' curriculum design using CfE as a guiding document. Her model involves three interactive spaces or "arenas" of the curriculum development process. The first of these arenas is the *design arena* in which teachers plan, select, design, invent and adapt learning tasks for students. In the Scottish context, teachers work collaboratively or individually to select and modify tasks from previous curricula or create new tasks that correspond to the learning objectives and experiences outlined in CfE. In the *construction arena*, the tasks are enacted in the classroom and change shape in accordance with students' responses to them. Remillard (1999, p. 322) asserts that teachers' enactments tend to be improvised, responsive and include "in-action" decisions. Remillard refers to the third arena of curriculum development as the *curriculum mapping arena*. In the mapping arena, teachers make decisions related to the content, organization, and sequencing of the curriculum. In reference to this study, we focused primarily on the science teachers' curriculum design and mapping activities rather than on the enacted curriculum.

Second, we included the theoretical construct of *teacher beliefs* as a frame for our study. Research since the 1980s on teacher beliefs has shown them to be highly significant factors influencing the decisions and actions of teachers (Bryan, 2012; Nespor, 1987; Pajares, 1992; Wallace, 2014). Teachers develop belief sets based on *individual* autobiographies, experiences, knowledge and emotions (Bryan, 2012; Nespor, 1987). Thus, in addition to a composite description of curriculum development experience, we give an account of teachers' individual experiences in light of their beliefs. We assert that the individual belief sets that teachers hold about science teaching play a significant role in the way they develop curriculum using CfE and must be taken into account (Priestley, Biesta, & Robinson, 2013). Further, individual beliefs add richness and texture to the teachers' descriptions of the curriculum development process and provide additional horizons or meanings for the phenomenon (Moustakas, 1994).

Third, we utilized the construct of *teacher agency* to illustrate how teachers are able to make sense of curriculum policy and develop the curriculum in myriad ways in their professional settings. To frame this study, we follow scholars (Priestley et al., 2015; Biesta & Tedder, 2007) who conceptualize agency not as personal capacity, but rather as an emergent phenomenon; as something to be achieved rather than a quality to be possessed by the individual. Agency in this view is always achieved via a coming together of personal capacity and contextual conditions, and can be seen as the socially (and materially) mediated ability to act (Biesta & Tedder, 2007).

Agency viewed not as a quality that a person "has", but rather as what s/he is able to "do" (Biesta & Tedder, 2007) has important implications for teachers engaging with curriculum policy. In this context, full ecological understanding of teacher agency has to account for individual factors (such as knowledge and beliefs), structural factors (such as the availability of relational resources) and cultural factors (for example, collective ways of thinking about the science curriculum). This view of agency also allows us to delineate between the commonly understood view of autonomy (as a comparative lack of regulation) and agency. Teachers may be granted additional autonomy, yet have trouble achieving agency due to difficult contexts and/or lack of resources. In particular, this study examines "agentic orientations," a term referred to by Biesta and Tedder (2007, p. 137), to signify those conscious thoughts, ranging from past experiences to future aspirations, about how one might respond to educational problems shaped in both the personal and social realm. Thus, we investigate how the human experience of curriculum development is related to the agentic orientations of the participant science teachers with their individual beliefs, knowledge bases, and school contexts.

Including the theoretical frame of teacher agency allows us to characterize the phenomenon of curriculum development in terms of science teachers' conceptions of and desires for action within their teaching realm. While beliefs represent a filter through which teachers make curriculum development decisions, agentic orientations may predict what actions they might take within their particular contexts to effect change. The three theoretical constructs, teacher as curriculum developer, beliefs and agency, are connected through their synergy to produce the teaching practices and therefore potential learning that students will experience in the classroom. The CfE curriculum document is the starting place for a "cascade of interpretations" (Hume & Coll, 2010) that eventually reach the level of the school, science department and individual classroom teacher. It is through their work as curriculum developers that science teachers design curriculum through the lens of their beliefs. They then carry forward their agency, within the constraints of their ecological context, to shape the teaching and learning experiences that are enacted in their practice.

Teachers' perceptions of curriculum development

Research has shown that, not surprisingly, individual teachers differ in their cognitive commitments in regards to curriculum development (Meirink, Meijer, Verloop & Bergen, 2009; Remillard, 1999, 2005; Shawer, 2010). Shawer (2010) created a taxonomy for teachers' levels of engagement with curriculum development in the context of teaching college English as a foreign language. He grouped teachers according to their strategies and depth with curriculum development as either: (a) *curriculum developers*- those who started with the textbook and then expanded, adapted or supplemented it with outside resources according to the needs and interests of their students; (b) *curriculum makers*- those who began with a needs assessment, then created their own thematic curriculum structures and wrote their own curriculum material, choosing carefully from available resources; or (c) *curriculum transmitters*- those who followed the textbook and teacher's guide and treated the textbook as the content in terms of the order of presentation. Shawer's study effectively shows how teachers' curriculum decisions can alter what students can potentially learn. Similarly, Remillard (1999) contrasted the ways two middle school math teachers "read" the curriculum, one as a collection of lessons to be delivered and the other as an idea template from which to develop her own lessons. Thus, teachers who orient themselves as *curriculum makers* may be more amenable to change that involves increased responsibility for curriculum creation.

Research indicates that science teachers have expressed negative experiences of curriculum development when called upon to respond to change mandates. Melville (2008) used Gee's (2003) framework of six criteria required for the adoption of a new language to analyze Tasmanian science teachers' experience of incorporating new curriculum standards into their lesson planning. For example, to adopt new curriculum language, teachers must be able to blend it into their identities, experience it in lived ways, and deliberately choose to use new language forms instead of their previous ones. Melville indicated several mismatches between the new curriculum standards and the teachers' ongoing ways of thinking and talking. Many teachers who don't understand the purposes or share the underlying philosophies of new curriculum goals are reluctant to shift their personal teaching orientations. Several studies have indicated that curriculum innovation is taken up much more readily when teachers' personal interpretive frameworks match the underlying rationale for the curriculum change (März & Kelchtermans, 2013, Melville 2008; Wallace & Priestley, 2011). In some cases, teachers have been shown to adopt the discourse of the innovation and publicly support it without fundamentally changing their teaching practices (Priestley et al., 2013; Yerrick, Park & Nugent, 1997).

On the other hand, some studies have shown that teachers can utilize new curriculum language to justify and springboard changes that they desire. Spillane (1999) found that four of twenty-five secondary mathematics teachers embraced change toward more constructivist formulations of math lessons because they understood that the new curriculum had the potential to bring about deeper conceptual understandings for their students. Similarly, Roehrig, Kruse and Kern (2006) found that a few chemistry teachers in their professional development project welcomed an inquiry-based innovation, because they realized their students did not learn well from lecture. Thus, the experience of curriculum development in the context of innovation depends of a multitude of factors including teachers' dissatisfaction with the former curriculum, a congruence between the philosophies and epistemologies expressed in the language of the curriculum document with personal beliefs, as well as other factors such as levels of content knowledge, pedagogical content knowledge, school administrative support, time and resources (Hume & Coll, 2010; März & Kelchtermans, 2013; Melville, 2008; Roehrig, Kruse & Kern, 2006; Spillane, 1999).

The relevance of teacher beliefs to curriculum development

Literature on teacher beliefs in relation to curriculum reform in many ways parallels the literature on teacher perceptions. The *teacher beliefs* construct has been interpreted a number of ways by different researchers (Wallace, 2014). Regardless of these different definitions, science educators agree that teachers "filter" new knowledge introduced to them in curriculum innovations through their beliefs systems about science teaching and learning. Research into how science teacher beliefs support or diminish teachers' enactment of curriculum innovation is abundant has been summarized well elsewhere (Bryan, 2012; Wallace, 2014). Teachers have been shown to promote, modify or subvert an innovation, depending on how well the innovation corresponds with their beliefs (Bryan, 2012; Kelly, 1999; Priestley et al., 2012; Wallace & Priestley, 2011; van Driel, Bulte, & Verloop, 2005; Yerrick, Parke & Nugent, 1997). Further, teacher collaboration with peers may foster belief change in favor of curriculum innovations. While experienced teacher beliefs are difficult to change, those who actively engage in experimentation, such as action research, within supportive teams may adopt more positive beliefs about innovations (Meirink et al., 2009; Shawer, 2010).

Teachers who modify the curriculum more significantly away from the official standards may have belief sets which differ from the philosophy of the mandated curriculum. For example, Priestley and colleagues (2012) found that two high school teachers of life science differed extensively in their curriculum enactment. One teacher who believed students were passive recipients of knowledge enacted the course as lecture-based, convergent and didactic. He adhered closely to the official curriculum policy documents. The second teacher enacted a much more divergent course experience, as she believed in using the life science curriculum to open up thinking possibilities. She used the official curriculum as more of a broad template for lesson development and included a variety of ways for students to engage the content. There is some evidence that science teachers generate positive beliefs about reform from professional development, but keep newer beliefs more peripheral, continuing to operate on their core belief sets. For example, studies by Trumbell, Scarano and Bonney (2006) and Waters-Adams (2006) found that teachers espoused new understandings of the nature of science after professional development sessions, but continued to teach science as a collection of facts. Long-term professional development with these teachers eventually led to some of them opening up instruction into more constructivist-oriented forms. In summary, science teachers respond to curriculum mandates in individual ways, according to their belief sets, and in accordance with socio-cultural factors within their immediate teaching environment.

Rationale for the study

There have been many studies of how and why science teachers have negative experiences of curriculum development under change mandates and how teachers fail to incorporate innovations that run counter to their teaching beliefs (Bryan, 2012; Melville, 2008; Wallace, 2014). Also, some studies have shown how positive factors can contribute to teachers' adoption of new philosophies and pedagogical techniques. Some of these factors include having personal constructivist epistemologies, being in agreement with the principles for change and participating in collaborative team work. However, there are few, if any, studies, exploring how teachers perceive changes in their roles as curriculum developers in light of new curriculum mandates. The current study examined, not only which changes to the official curriculum teachers found most salient for their work, but also which cognitive activities (including dispositions, experiences, knowledge commitments and professional responsibilities) were concomitant with implementing these changes. Further, we sought to examine how individual beliefs and agentic orientations interact with these new roles for science curriculum developers and point to potential for change through teacher agency. The study contributes to the knowledge base of science teacher thinking by analyzing teachers' perceptions about their work as curriculum developers within the context of change and individual variations to those perceptions.

Methods

Research design

The research design and methodological perspective for this study is empirical phenomenology. Phenomenology is a German philosophical discipline used to frame studies in the social sciences, particularly the study of human experience. It may be considered the study of structures of experience and consciousness (Moustakas, 1994). An influential phenomenologist, Husserl (2002) emphasized phenomenology as "*a science of essential Being* . . . a science which aims exclusively as establishing 'knowledge of essences'" (Husserl, 2002, p. 44, italics in original). As such, phenomenologists seek the true essence of human experience, by bringing intuition to bear on objects, perception, memory and fantasy. Individual experiences can be combined into various levels of universality (Husserl, 1931), thus producing *composite* or more generalized structures of experience (Moustakas, 1994). The phenomenon of interest in the current study is the experience of science teacher as curriculum developer within the context of Scotland's CfE.

The method of empirical phenomenology includes having participants describe their original experiences of a phenomenon and the situations in which the phenomenon occurred. The researcher then uses these descriptions as the basis for a reflective structural analysis with the aim of portraying the richness and substance of the experience (Moustakas, 1994). This study aimed to investigate the phenomenon of teacher curriculum development for Scottish science teachers in the context of mandated use of CfE. The study included the dimensions of: (a) what teachers experienced as the most significant innovations that shape their role as curriculum developers; (b) how the meaning of what it is to be a science curriculum developer has shifted with the advent of the CfE, from the teachers' composite perspective; and (c) how teachers view the CfE innovations in light of their individual beliefs and agentic orientations.

Context of the study

The study took place in Scotland in May, 2015. Two local school authorities were involved in the research. Teachers from three public schools and one Catholic school participated in the study. Pseudonyms for the schools are Clarke Academy, Bellgate Grammar, Our Lady of the Woods High School and Peterburgh High School. The study focused on the experiences of teacher curriculum development for secondary grades 1, 2 and 3 (S1, S2 and S3; equivalent to grades 7, 8 and 9), because the researchers were interested in curriculum development related to courses enrolled in by most or all students, rather than advanced course work in specialized subjects. The first author visited on-site at three of the four schools. She met with one teacher from the fourth school outside of school at a coffee shop, due to logistical limitations.

Participants

Several of the participants in the study were from schools that had done professional development workshops with the second author and therefore had a positive relationship with him and the university at which he works. Permission to conduct research at the schools was obtained from both the local education authorities and the head teachers of the schools. There were seven teacher participants in the study. The sample was a sample of convenience in that the participants were volunteers who gave permission to be interviewed and observed during one class session. The participants are not necessarily representative of all science teachers and this may be viewed as a limitation of the study. They are likely to be representative of "high involvement" teachers (Lasky, 2005) who were active in many areas of school life. All of the participants met the basic requirement of phenomenological research in that they have a deep level of experience with the phenomenon of teacher science curriculum development with CfE.

The participants are described in Table 1. Note that most Scottish science teachers teach at least one class in the lower grades, S1 and/or S2 in addition to their subject specialty. All of the teacher participants are of Caucasian Scottish ethnicity and are identified by pseudonyms. Participants from Clarke Academy included Keira and Robert. Keira is a female physics teacher who had been teaching for four years at the time of the study. Robert is a male biology teacher with about 15 years of teaching experience at the time of the study. Participants from Bellgate Grammar included Lauren, a female biology teacher with about 12 years of teaching experience and Lexie, a female biology teacher with 5 years of experience. Participants from Our Lady of the Woods included Ian, a physics teachers with 4 years of teaching experience and Helen, a chemistry teacher with over 25 years of experience. Finally, Louise, a biology teacher, was the participant from Peterburgh High School. She had about 18 years teaching experience at the time of the study and in addition, works as an instructor for a university teacher education program in biology.

Table 1
Study Participants Characteristics

Name	Gender	Years Teaching	Subject	School	Ethnicity
Robert	Male	15	Biology	Clarke Academy	Scottish
Keira	Female	4	Physics	Clarke Academy	Scottish
Lauren	Female	12	Biology	Bellgate Grammar	Scottish
Lexie	Female	5	Biology	Bellgate Grammar	Scottish
Ian	Male	4	Physics	Our Lady of the Woods	Scottish
Helen	Female	25+	Chemistry	Our Lady of the Woods	Scottish
Louise	Female	18	Biology	Peterburgh High	Scottish

Data collection

The first author collected and analyzed the data. Data sources included semi-structured interviews and classroom observations. Moustakas (1994) recommends using the long interview as the primary source of data collection in empirical phenomenological studies. Interviews were conducted with all seven of the participants. Three of the interviews were conducted individually, while four of the interviews were conducted with two teachers at a time, due to the teachers' time constraints. The interviews were approximately 70 minutes in duration. The interview protocol is shown in Appendix B. Five of the seven teachers were observed teaching during one class period, as time and logistics allowed. The purpose of the classroom observations was to provide a second method of data collection to build a richer picture of curriculum design and decision making for individual teachers. The observations were used to examine how lessons designed using CfE as a guideline document looked in the classroom and to compare this view with the views espoused in the teacher interviews (Richardson, 1996). The interview and observation data illuminates the teachers' experience of the design and mapping arenas of curriculum development (Remillard, 1999). The observations were of insufficient duration to draw conclusions about the enactment arena of curriculum development.

Data analysis

All data was transcribed and then entered into the qualitative analysis software program known as Atlas.ti. The four classic phases of data analysis in empirical phenomenology were followed to analyze the data: (a) *epoche*- (from the Greek for abstain) the act of setting aside prior knowledge, conceptions, judgments and commitments about the phenomenon; allowing the researcher to see it without the biases of everyday knowledge; (b) *phenomenological reduction*- similar to other qualitative data analysis methods, this involves separating, differentiating and determining multiple meanings of each data segment, then reducing these meanings to categories and themes; (c) *imaginative variation*- the practice of the researcher using her imagination to compare and contrast aspects of the phenomena and to hypothesize about how these relate to one another; and (d) *syntheses of meanings*- having explored the phenomena for individual participants, the researcher combines and distills the meaning of the phenomena for the group as a whole (Husserl, 1931; Moustakas, 1994).

The data corpus consisted of transcribed interviews and written field notes from classroom observations. Data reduction consisted of first parsing data (both interview and observation) into units that represented unique ideas, then using a series of descriptive codes to capture the participants' meanings. For example, data segments were first described as being germane to one of the research questions. These broader categories included, *beliefs, agentic orientations, characteristics of CfE, assessment, collegiality, planning,* and *teacher knowledge*. Each data excerpt was further described in terms of the science teachers' experiences, using additional second and third level interpretive codes. For example, the interview quote, "So I think the idea was brilliant and I think we wish we could go back to that, but in reality we're stuck with what we have to get them to pass- to leave school because that's ultimately what's important," was coded as "beliefs/reality of qualifications." The frequency with which certain codes were used was noted when developing the composite experience of change profile.

Methods for determining validity and reliability in empirical phenomenological research are still being debated in the literature (Finlay, 2009). Central to the philosophy of phenomenology (Husserl, 1931), an important feature of validity is for the researcher to "bracket" her ideas; to look with fresh eyes on the phenomenon of interest. Second is for the researcher to report the participants' descriptions of the phenomenon as accurately as possible, refraining from over interpretation. To this end, we have gone back and forth from the data to the text to check for clear exemplars and exceptions to our assertions. However, the phenomenological researcher also relies on "intersubjectivity," the ability for the researcher to share cognition, language and emotions with the participants. That is, although the researcher reports the participants' experiences of the phenomena in their own words as much as possible, the identification of the researcher to the participants' experiences can validate a common understanding as reported in a study (Finlay, 2009, Hein & Austin, 2001; Moustakas, 1994). Intersubjectivity was employed in this study, as the first author has herself been a secondary science teacher who practiced under curriculum mandates and was also familiar with Scottish classrooms.

Results

In this study, we asked the following research questions:

- What do Scottish secondary science teachers experience as being the most significant innovations in the science CfE that modify their work as curriculum developers?

- How has the composite experience of what it means to be a science teacher curriculum developer shifted with the advent of the CfE as the mandated curriculum?
- How do individual teachers experience curriculum development with CfE in conjunction with their core science teaching beliefs and agentic orientations?

The results section is organized into three main parts. The first section (corresponding to research question one) addresses characteristics of the CfE document that teachers experienced as being the most impactful for developing their daily lessons. While this section basically confirms that the CfE is paralleling other global national curricula in trends away from content and toward scientific investigation, it nevertheless provides important background information for parts two and three of the results. We have included the teachers' ideas on the most salient changes in order to clarify how these perceived changes in the goals and purposes of school science have: (a) shifted their ideas of what it means to be a science curriculum developer at the level of the classroom (corresponding to research question two); and (b) aligned or not aligned with their individual beliefs and agentic orientations (corresponding to research question three). The remainder of the results section addresses those two questions.

Significant innovations in the CfE that impact curriculum development

Assertion One: Adherence to the CfE achievement objectives has generated movement away from teaching and assessing science content and toward teaching and assessing research skills. Overall, the science teachers' experience of responding to the new curriculum objectives was that of designing lessons to foster intellectual thinking around scientific problems. The teachers asserted that the designed and mapped curricula they were constructing reflected a new emphasis on scientific thinking and investigation skills. The Scottish teachers referred to these as "research skills," however these were broadly conceived by all of them to include both science-related skills and general academic skills. The science-related skills included questioning, predicting, problem solving, experimental design, data analysis, scientific communication and lab procedures. In addition to science related skills, the teachers' conceptions of "research skills" also included more general academic skills, such as literacy and numeracy skills, contributing to group work, being effective listeners, writing, finding relevant content on the Internet, and developing confidence in learning. The teachers attributed this shift from content to skills to a number of factors including: (a) less specified content within the CfE achievement objectives; (b) the fact that since primary schools were doing more investigation and they needed to continue to challenge students; (c) the realization that students can find science content in resources (e. g. the Internet); and (d) the need to prepare students for rigorous capstone science investigations in the upper grade science classes.

For example, Lauren, an S3 biology teacher, highlighted the importance of giving students a science "skill set" so that they "might go about an investigation from a scientific point of view." When asked to define her understanding of "skills" in the interview, she stated:

> So for me probably communication skills, expressing their opinion, understanding other people's opinion, doing research to make their own opinion. But, also, like physical science skills of measuring, planning experiments, looking at a problem, thinking about how to solve that problem would be what I would mean by skills (interview, 05/12/2015).

Lauren asserted that science content knowledge is constantly changing, so a skills-based approach is more useful than a content-based approach. Lauren viewed the CfE objectives and new national assessments as promoters of curriculum development towards scientific investigation. Further, Lauren strongly supported Scotland's previously emphasized learning initiative, "Assessment is for Learning," in which students receive specific feedback and use the feedback to improve a work sample, rather than just a grade. Lauren's belief in the usefulness of formative assessment aligned well with her belief in teaching research skills. Classroom observation data indicated that one main focus of Lauren's instruction was to guide the students through a complete scientific investigation including background research, formulation of the steps of an experiment, writing up the experimental results, and producing a poster to communicate the findings. She was able to assess pieces of this investigation as it progressed, having students rework portions that were not complete or accurate.

Also, as development of the CfE into classroom lessons has progressed, the teachers have realized that teaching investigation skills early and reviewing them frequently will be necessary for students to pass investigation-based national qualification exams. They have developed a composite awareness that with the new curriculum and associated changes to assessment, more research skill development needed to be initiated into the lower secondary grades. Keira, for instance, viewed the new early emphasis on skills development as being necessary to learn more detailed content in the upper grades.

> The issues that we're facing at the moment which again goes back to S1 and S2 is when we had been focusing on content we weren't preparing the pupils adequately to cope with National 5 [an official qualification course]. We're having to at the moment reinforce skills that should already be embedded, which is making it more difficult for pupils to access the content . . . If we start with the skills a lot earlier on then we can focus more on content and practice and application when it comes to National 3, National 4 and National 5 (interview, 05/11/2015).

Like other global science curricula designed to promote 21st century learning skills, CfE represents a trend from a content-focused approach to a scientific investigation-based approach (Achieve.Inc, undated; Hume & Coll, 2010; Sinnema & Aitken, 2013; Tao, Oliver & Venville, 2013). The composite experience of science teachers in this study indicates that, indeed, Scottish teachers are perceiving the new curriculum objectives as being more centered on skills-based pedagogy.

Assertion Two: Using the CfE as a curriculum guide has led to the experience of moving away from decontextualized science concepts to more contextualized, up-to-date and integrated science units.

A second characteristic of the science CfE that shaped daily lessons was the inclusion of contemporary science content that exhibits connections to the real world. There was a common data strand in which the teachers in the study voiced their appreciation at being able to teach through examples that the students could see in their daily lives. As stated by Keira:

> I think in physics, certainly, it is more up to date. We were certainly getting to the stage where we were talking about things like little grey tubes in televisions and electron guns, which children now have not seen these things. And when we're talking about how a radio functions . . . it's not how a radio functions anymore . . . it's just completely out of date and I think it's more in context as well (interview, 05/11/2015)

Keira viewed the emphasis on having students connect with real world examples, not only as an opportunity to learn significant science content, but also as a philosophical stance promoted by CfE for students to take classroom learning and extend it into everyday life. Keira regarded CfE as a 21st century curriculum, meaning that what is learned in school has relevance and meaning in the real world. That school topics can be extended into daily life and students can continue to research them is a novel idea not always promoted in official curriculum standards.

In Keira's case, this is a positive characteristic of curriculum development that will likely act as a promoter of the new curriculum principles into daily lesson design.

A focus on contextualized and real-world science was evidenced in Lexie's opening to a practical activity on heat transfer. Before beginning her inquiry-based lesson for designing a well-insulated "building," she first had the students discuss a problem about where in their houses the most heat would be lost and brainstorm their initial ideas on how they could make their own home better insulated. Lexie noted that an up to date curriculum in terms of the science content was greatly appreciated.

> Obviously content has become much more up-to-date than previously. I guess we were getting to the point that actually what I had studied at school was the same, but science has changed so much that we needed an up-to-date curriculum (interview 05, 12, 2015).

Like several other countries, Scotland appears to have incorporated more real world and contextualized problems and performances into its 21st century science (Achieve.Inc, undated; Sinnema & Aitken, 2013). However, the expectation for Scottish teachers to connect school-based practices with real world problems represent a change for them that is relevant to their views of what it means to be a science teacher curriculum developer in the context of CfE.

Shifts in the experience of what it means to be a science teacher curriculum developer

In this section, we address research question number two regarding how the teachers perceived changes to their roles as curriculum developers in response to the CfE mandate. The new curriculum language, achievement objectives and open-ended nature of the document have required teachers to change their approaches to daily lesson planning and curriculum mapping across their science courses. Through experiencing these practices, teachers indicated that the nature of their work as curriculum developers has taken on a new character.

Assertion Three: The science teacher's role in developing curriculum is to become a creative problem solver, who must consider both short and long-term consequences of curriculum design and mapping. Teachers in the study expressed that previously, daily lesson planning largely consisted of revising old lectures and experiments to teach the meaning of related science concepts, parsed out through the days. Now, under CfE, teachers view both the design and mapping processes as problem-solving activities. Related to this change include the need to incorporate more science specific skills, general academic skills and contextual applications into the curriculum as described above.

All seven of the participants mentioned the need for increased intellectual engagement with and problem solving for curriculum construction. In Robert's case, the mandate for more integration with real-world scenarios has been a driving factor for curriculum mapping across a unit. In the interview, he emphasized the need for more teacher "intellectual engagement" with lesson planning. He also cited lack of preparation for this deep level of planning in both initial and on-going teacher preparation as a major challenge to CfE implementation. He described aspects of the shift as follows:

> We're trying to change the culture. So my feeling is [that] the single biggest way we can improve our S1 and S2 teaching is to increase the intellectual engagement of the teacher in the lesson, rather than just sleepwalking through a script . . .
>
> [Science teachers previously] didn't know how to develop courses, they didn't know how to think about planning schemes of work, they went for an anatomized

> approach which was planning lesson by lesson rather than planning for seven or eight lessons with a narrative running through them (interview, 05/11/2015).

Robert's comments provide his personal perspective about why responding to the CfE mandate requires new and different cognitive activity; that is, teachers now need to actively construct units that lead to more than just concept acquisition. In Robert's view, sets of lesson plans need to build to bigger themes or meanings having to do with societal connections. He now strives for units that "add up to more than a sum of their parts" and that include the integration of real life contexts, such as the impact of DNA testing on society.

Another major factor, the incorporation of more science specific and general academic skills, both as introduced into daily plans and incorporated more strategically into curriculum mapping, has also fostered a problem-solving perspective on lesson planning for the participants. The excerpts below illustrate how the participants are using analysis and experimentation to incorporate more science and general academic skills into the curriculum.

> Lexie: Yeah, we spent a lot of time looking at the experience and outcomes that we wanted to meet and how we felt it would be best to meet that- making sure they had a range of activities . . . so we can share, well we're hoping they are going to learn at the start of that [and] looking back have they learnt it for right through as well [?] (interview, 05/12/2015)

> Keira: I've mapped the outcomes across our cluster and they [primary schools] are covering level 1 and level 2 [of curriculum standards], [so]the majority of level 2 is being covered already . . . so we're hoping that when we review the curriculum we're going to focus on skills, level 3 and introducing level 4 to stop people [students] switching off (interview, 05/11/2015).

Lauren: We're still trialling things out and learning . . . (interview, 05/12/2015)

Louise: We identified this [content] area so they've [science teachers at her school] have developed a lot of materials that's now going to be trialed in Peterburgh to try and up-skill children on things like critical thinking, evaluation, [and] just basic skills (interview, 05/13/2015).

Science teachers are now experiencing curriculum development as analysis and purposeful planning to meet particular skill and content aims. As indicated in Lexie's excerpt, "we spent a lot of time looking at the experience and outcomes" and "have they learn't it for right through as well [?]," indicate a concern and hope that the skills and concepts taught earlier will be maintained into the higher grades. Second, Keira' quote indicates the activity of mapping skills to articulate with the primary curriculum, in addition to throughout secondary. Third, teachers are creating new materials to promote science and academic skills and experimenting with these in the classroom, as Louise stated to "try and up-skill children on things like critical think, evaluation, [and] just basic skills."

Assertion Four: The nature of curriculum development has also changed, from planning based on an authoritative epistemology of science, to planning for instruction that promotes students to create their own science knowledge. There is a newly perceived requirement for teachers to involve students in the creation and application of their own science knowledge. The teachers noted that the new standards have compelled them to include opportunities for students to generate and assess knowledge through their use of science specific and general academic skills. The language of the CfE requires students to generate their own data patterns, conclusions and generalizations from their science lessons, rather than engage in verification labs.

Helen, for example, noted that the science CfE emphasized "creating and applying knowledge" much more than the previous curriculum. She posited that these overarching goals were more difficult to teach and assess than traditional content. She indicated how in the previous curriculum, laboratory activities were generally focused on one take away concept, for example, that metals are good conductors of heat. With the new paradigm, she felt responsible for assessing her students' progress in thinking and reasoning, and for her, this was a more difficult teaching task. She explained how the skills emphasis impacted her teaching experience as follows.

> We're hoping that the skills that they actually develop will take them into lots of different kind of fields out there. And it's hard. A lot of the emphasis now is on investigative skills and what does that really entail, you know? It's creating . . . applying knowledge as well. It's understanding how much they've actually taken in, how much can they apply these different skills . . . (interview, 05/14/2015).

Helen's comments suggest that new responsibilities of the science teacher in CfE context entailed mapping thinking skills onto the achievement objectives, determining appropriate levels for skill development and then assessing the children for progress in that development. For a veteran teacher like Helen, this was clearly a new way of thinking about the roles of a science teacher. Thus, in terms of epistemology, Helen's traditional thinking involved clearly communicating to students the scientific point of view. Now, she is challenged to design lessons from a new epistemological perspective that afford children the opportunities to draw their own conclusions based on thinking skills.

Louise also expressed a need for teachers to reconstruct an understanding of what it means to learn science. She noted that:

> [In the CfE lower level standards], they've pulled down a lot of the, some of the curriculum, from higher, which is application of knowledge and that was always the higher order thinking (interview, 5/13/2012).

> [So], how do you develop the skills and the language and the knowledge around that continuum up to the big idea? And, that's what, when I talk to children in the school, that's where the challenge, I always think, comes in. Because your saying to them, well . . . and it's the questioning you know, what if, how about . . . Good questioning so that the child starts, I mean it's all constructivism, but I mean you're trying to get them to construct you know their sort of ideas as well (interview, 5/14/2015).

In the first of these excerpts, Louise is affirming that the CfE early secondary curriculum includes higher order thinking skills for which science teachers must now design instruction. In the second, Louise is relating the planning work of the teachers to the need for children to construct their own knowledge. She asserted that with the advent of the CfE, teachers need to look upon meaningful questioning as characteristic of their development work.

Individual experiences, beliefs and agentic orientations

In this section of the article, we address research question three, by presenting three individual teacher profiles of curriculum development. The three profiled teachers, Robert, Keira and Ian, were purposefully chosen post data analysis to illustrate the science teachers who, at the time of the study, were most actively grappling with their next stages of curriculum development. We believe that intersections of the processes of curriculum development with personal beliefs and agentic orientations are best illustrated with the teachers who were on the cusp of bringing new practices into the classroom. Thus, this selection is driven by the theoretical framework and research questions (Miles & Huberman, 1994). We signify their agentic orientations with descriptive names below.

Robert. Robert was one of the more experienced teachers in the study, having taught science for 15 years with experiences both overseas and at the university level in addition to high school. As such, he has a wide repertoire of experience upon which to draw and has formed strong aspirations for using CfE. Among Robert's core pedagogical beliefs was the desire to teach young people general understandings about their world, especially human bodies and ecosystems, to foster students' connections between science and the everyday world, and to generate curiosity about science. He stated,

> Quite a lot of science teaching kind of gives them [the students] the structure but robs them of the curiosity . . . So I've always, I've tried to do all my science teaching in such a way it holds on to the curiosity (interview, 05/11/2015).

Robert expressed that there was a great deal of congruence with the science CfE and his core pedagogical beliefs. He described the science CfE as liberating, open and expansive. He stated that he connected strongly with the original "spirit" of the document, which was to honor teacher professionalism and autonomy.

> I see Curriculum for Excellence has really given me permission to teach the way I want to teach . . . I find it quite liberating actually . . . that's how I would see it, it gives me massive leeway to do what I think is best for me and the children (interview, 05/11/2015)!

Along with his enthusiasm for the congruence between his teaching beliefs and CfE, Robert also expressed a compelling agentic orientation for his science department to critically engage with the mapping arena of curriculum design (Remillard, 1999). He viewed CfE as a framing for professional action and curriculum engagement, rather than a recipe to follow. His approach to curriculum design, thus, may be described as a "curriculum maker" in Shawer's (2010) terms. Robert perceived the future of science teaching within the context of CfE as the development of critical thinking about the contemporary world for students.

Robert's background as an experienced science teacher who has seen initiatives come and go may afford him greater agency in his curriculum making. For example, he is working on designing a DNA profiling unit in S2 to foster the understanding of practical aspects of genetics. He expressed his agentic goals for the science department at his school in this way,

> For each of these little units we'll have somebody who's going to be the lead professional in that and go and do some development work, some capacity building . . . We're trying to change the culture, so my feeling is the single biggest way we can improve our S1, S2 teaching is to increase the intellectual engagement of the teacher in the lesson rather than just sleepwalking through a script . . . [I want teachers to have] the skills to plan a set of lessons which really effectively address the children's needs . . . [that] adds up to something more than the sum of its parts (interview, 05/11/2015)

Robert's classroom observation provided evidence of correspondence between his stated beliefs, agentic orientations and teaching practices. He started an S2 lesson by projecting an advertisement for a personal DNA screening that could give one information about ancestry and possible genetic diseases. He asked the students to write down two advantages and two disadvantages of having access to such information. This exercise was followed by a short, but vigorous discussion about whether the children would want to be told about possible heritable diseases they might carry. During the balance of the class session, the students watched the conclusion of a commercial film about DNA inheritance, "GATTACA," then answered questions about both the genetics and ethical decisions portrayed in the film. Finally, the class generated a list of overall issues involved in genetic engineering. This lesson illustrated Robert's beliefs in designing lessons that deviated from narrow learning objectives, that were responsive to students' interests and that fostered understandings about the world around them. It also demonstrated his agentic commitment to achieving change by pioneering innovative lessons in his department. Robert was optimistic that the social and cultural climate in his department at the time was such that the "spirit" of CfE could be translated into curriculum design and curriculum mapping decisions.

Keira. Keira had only four years of teaching experience at the time of the study and thus, has taught only during the implementation of CfE. Keira believed that a primary goal of science teaching is to "develop them [the student] as a person . . . develop the whole child, that's what I go for." She expressed her interest in supporting children in the science classroom so that they have a positive experience of science. She believed that the "personalization" aspects of CfE were compatible with her beliefs in developing the whole child. In other words, the autonomy of the teacher to pursue some of the children's interests was in line with her child-centered beliefs.

Second, Keira expressed a strong belief in developing a range of "skills" in the children, including social, communicative, numeracy, literacy and scientific investigation skills. A belief in developing general academic skills parallels the stated beliefs of other teachers in the study and mirrors language in official CfE documents. Further, she believed it is vital that earlier science classes prepare students adequately for the new national qualification exams in the upper years, which call for sophisticated use of science investigation skills. Therefore, we observe that Keira has incorporated the language of the CfE into statements about her own espoused beliefs. Our interpretation is that Keira views CfE as a map to inform her practice, which gives her guidance, as she is in the earlier years of teaching, yet at the same time constrains her agency to exercise other aspects of her belief set, such as giving children choice in the topics they study.

Keira's adoption of the CfE as a skills-based curriculum map is reflected in her agentic orientations. She appears to be anxious about accountability demands and tends to be acting on ways to implement the skills-based approach, rather than any of her other personal aspirations. For example, Keira has been part of a team that has been observing primary school science lessons in order to better align what is taught in S1 and S2 in terms of both concepts and skills development with what children are experiencing in grades 5 and 6. She noted that the rigorous requirements for students to carry out their own investigations in the upper grades necessitated working these investigation skills into the lower grades. She stated:

> Maybe we should be using the science specialist [science teacher] to really embed the skills that they can take forward 'cause they have the knowledge there but they don't really know what to do with it and how to apply it in a real life setting. So I think we're definitely moving towards skills-based learning (interview, 05/11/2015).

Keira appears to have integrated CfE rhetoric into her own belief set and sees her agency as a promoter of scientific thinking skills, especially for the first two grades of secondary school. For her, CfE is both a helpful guideline for informing her of what needs to be done for students to pass their exams, and a limitation on developing her own unique science teaching aspirations. This resonates with earlier research in Scotland (Priestley, Biesta & Robinson, 2015), which suggests that the agency of early career teachers can be restricted when they rely on the concepts and language of current policy to articulate their practice, rather than being able to fall back on a more expansive educational discourse formed through engagement with educational literature, or through experience of successive cycles of curriculum policy.

Keira openly stated that the lesson the researcher would observe in class was based on the department's first version of implementing the science CfE. Starting in 2011, science teachers at the school had worked collaboratively to write a series of specific learning objectives related to the broader CfE objectives, then wrote a series of fairly tightly prescribed lessons for teachers to use. As such, Keira's lesson did not necessarily reflect her most current beliefs or agentic orientations surrounding the science CfE. Therefore, the observation data can be considered a contrasting example to newer curriculum development at the school (e. g. Robert's lesson). Her lesson began with a presentation of the learning objective in a traditional format. She then proceeded to lead a discussion with the students about where they find rust in everyday life and the effects of acid rain. Third, the students conducted a verification lab for rusting nails in a variety of acid concentrations, then finished with a wrap up discussion.

Ian. Ian was another fairly new teacher (fifth year at the time of the study) who lacks experience teaching under previous national curricula. When asked about his core beliefs for the purposes of teaching science to young people, like Keira, Ian stated that he viewed one purpose of early secondary school to be "primarily to enhance and develop their skills . . . to make them scientifically literate for upper school." Some examples of these skills for Ian included students doing their own research, working in teams, making presentations and developing confidence. Other important espoused beliefs for Ian were putting science in a real world context, making science relevant, and applying science to the outside world. These stated beliefs parallel the official rhetoric of the science CfE that emphasizes skills and real world connections.

However, when asked how he felt CfE aligned with his core beliefs in teaching science, Ian stated, "On paper, it sounds good. [But exams,] that's the only thing that counts at the end of the day, the results." Ian also viewed CfE as causing more heterogeneous grouping and less tracking by ability groups in science. Ian believed that teaching these multi-level abilities in one class is challenging and that higher level thinking may be beyond some of his students' abilities.

> And if they're in a class, you know, with who [sic] they believe is more intelligent pupils, then they automatically turn up and think, 'well this is over, this is above my head. I won't really try, it's game over (interview, 05/14/2015).'

A discrepancy between Ian's initial espoused beliefs and his teaching was observed during the observation of an S2 class. The objective of the lesson was for students to become familiar with the way chemical reactions are written, including being able to identify the reactants, products and that the plus sign and arrow indicated a reaction. The students spent the majority of the lesson filling in a worksheet in their booklets to write symbolic formulas from word formulas (although they did not need to generate the chemical compound symbols themselves). The students then played a matching game for word and symbolic formulas, using a card sort. Finally, they played a game by writing correct answers to convergent questions on small white "show me" boards. Although he engaged the students through discussion and kinesthetic activity in the observed lesson, Ian did not extend the concept of chemical equations to a real world context, nor did he engage the students' higher level thinking skills.

While Ian adopted language from the CfE into his espoused beliefs in the interview, his science teaching enactment indicated loyalty to alternative beliefs sets. Our interpretation is that there is dissonance between the philosophies of the science CfE on the one hand, and Ian's core beliefs in traditional ways to teach science, the demands of an exam-driven curriculum and the perceived limited abilities of students on the other. This seems to offer a powerful example of a situation where a teacher's beliefs – about education, about students and about the systemic demands of assessment/qualification – may considerably limit his or her achievement of professional agency toward change. Ian may be more comfortable with a traditional type of teaching and learning in which scientific thinking skills were emphasized less and content and verification labs were emphasized more. He felt that the despite the implementation of CfE, his head teacher was still most concerned about achievement as viewed in exam scores. These beliefs and skepticism about the about the efficacy of CfE to meet the learning needs of all of his students was reflected in his agentic orientations toward curriculum development. Ian described his current curriculum mapping activity as follows:

> I'm doing that just now [curriculum design] for the first year [S1], first year science. We've got three units, a chemistry, a biology and a physics unit and I'm just making them up. They already existed but I was given the task to take them and try and cut out as much work which doesn't cover any of the [CfE] experiences and outcomes . . . I'm trying to cut out as much as I can, making it less about writing and, you know, less about summative assessment and much more skill-based, more investigation (interview, 05/14/2015).

Ian expressed that he is working towards the major reform-based changes in the document, emphasizing content less and investigative skills more. In that way, he is practicing his agentic orientations to comply with the mandate for curriculum change and prepare students for new investigation-based assessments. His approach to doing this, however, is more piece-meal, less collaborative, and less visionary than the approaches to curriculum mapping suggested by Robert and Keira. Whereas, Robert is promoting a visionary curriculum, relating content to 21st century science, and Keira is engaged in using the CfE as a guide for curriculum mapping, Ian's approach is to take the previous curriculum materials and look for places to cut content and insert scientific skills development. In this way, he is attempting to use the "fallback" technique of changing some pedagogical techniques without fully understanding or supporting their long-term consequences for students. We hypothesize these actions create tensions and insecurity that surface for him daily as he develops his lesson plans.

Therefore, across these three profiles, we observe that despite dealing with a new common curriculum language and experiencing similar pressures on curriculum development, these participants are using their agentic orientations to shape instruction differently. Robert is taking the spirit of the document to heart and emphasizing real world connections. Keira is working hard to incorporate science specific and general academic skills into long term plans and Ian is introducing skills in a more piecemeal fashion into older content with which he and his colleagues are comfortable. We can imagine that within their contextual constraints, the agency achieved by each of the three teachers will influence the learning that takes place in their classrooms.

Discussion

Significance of the study

There are two significant findings emerging from this research. First, the study more finely unpacks the inherent dispositions, experiences, knowledge commitments and professional responsibilities that study participants found necessary to consider and engage with in order to implement the CfE. Findings about progressive cognitive commitments necessary for change stand in contrast to the results of multiple studies indicating how and why science teachers resist curricular change (Bryan, 2012; Cronin-Jones, 1991; Kelly, 1999; Melville, 2008; van Driel et al., 2005; Yerrick, Parke, & Nugent, 1997). Characterizing these common cognitive commitments (Spillane, 2002) provides a more complete understanding of what is involved in enacting curriculum mandates in the science classroom, at least in this case. The recognition of these cognitive commitments may provide clues for developing a model of professional development that is evidence-based, comprehensive, and clear to science teachers.

This study confirms previous studies that indicated that changes to teaching practices often require underlying changes to teachers' epsistemologies, language and beliefs about science teaching and learning (Bryan, 2012; März & Kelchtermans, 2013; Melville 2008; Sahlberg, 2011a, 2011, b; Supovitz, 2008; Wallace & Priestley, 2011). Sahlberg (2011a, 2011b) has discussed how, in the case of Finland, there has been a gradual change toward reformed-based practices across three decades. The first phase of this change, beginning in the 1980s, was "rethinking the theoretical and methodological foundations of schooling" (Sahlberg, 2011b). Teachers and the public were involved in setting priorities for critical and independent thinking amongst their citizens and became accustomed to a constructivist view of learning. Sahlberg (2011a) highlighted Finnish success with the important issue of modifying teachers' theories of knowledge. According to Sahlberg (2011a), systematic preparatory work to develop teachers' epistemological thinking was a prerequisite for successful development of a different kind of curriculum, without which the reforms could not be fully enacted. We have emphasized Sahlberg's (2011a) assertion regarding teachers' epistemological thinking in Finland in order to highlight how our study contributes to the idea of possible gradual epistemological change for teachers in other contexts.

In the current study, we have identified a number of cognitive activities, or perhaps some transitional steps, that science teachers may engage with on a continuum toward achieving more constructivist epistemologies and practices of science learning. The case of Scotland is striking in that the change from teacher as deliverer of information to teacher as curriculum developer has happened across such a short and recent period of time. Newer cognitive activities engaged in by Scottish secondary science teachers include: (a) analyzing the CfE document to discern the most significant areas or themes for change (e. g. increased need for scientific investigation skills, increased contextualization to real world science); (b) reflecting on the ways that science teacher curriculum development is a problem-solving endeavor; (c) undertaking the complex processes of curriculum mapping, from primary school all the way through national qualification exams; and (d) recognizing that the epistemological frame for students' science learning has changed and providing opportunities for students to create and apply knowledge. These cognitive commitments were derived from the teachers' phenomenological experiences of curriculum development in this study. In other words, we have produced a grounded analysis of potential shifts in teacher thinking that accompany the role of science teacher as curriculum developer in Scotland. The contribution of this study is the illumination of specific teacher thinking requirements that help unpack requirements for curriculum change at a deeper level of explanation than previous studies.

A second significant finding of this study is that nationally mandated curriculum implementation can provide impetus for teacher change within certain provisos, for example: (a) that teacher curriculum development involves analyzing the curriculum documents to find and interpret implicit purposes and principles; (b) that change is fundamentally a matter of how teachers are able to achieve agency as they mediate the new policy within their social settings; and (c) that individual teacher beliefs and agentic orientations will continue to mold interpretations into diverging form of change, similar to previous studies (Bryan, 2012; Priestley et al., 2013; Wallace, 2014). Despite the common experiences of interpreting the implicit purposes in the document, engaging in long-term problem solving, recognizing changes to epistemological underpinnings and meeting new and stiff accountability challenges, teachers still desire to achieve agency in their own individual ways.

For example, Robert was full of enthusiasm about possible changes to both daily science lesson design and curriculum mapping with the advent of CfE. His desire is for his fellow teachers to engage more intellectually with curriculum mapping, so that students will develop scientific meanings relevant to their everyday lives and interests. He is willing to take a leadership role in curriculum development in this regard. Further research is warranted to elucidate what teachers like Robert are able to accomplish within the ecologies of their teaching environments. In other words, what agency arises as a combination of CfE, Robert's beliefs, the reality of ensuing accountability measures, and other social, cultural and contextual factors in his school setting? In contrast, Ian's approach to curriculum development at this stage is largely superficial. Ian described cutting out some content pieces of the curriculum in order to provide time for more teaching of scientific practices and general academic skills. Ian may be representative of some number of Scottish science teachers who are hesitant about change. Future research is needed to follow the stories of these teachers as well.

Responding to trends in reformed science curriculum

The research identified two curriculum innovations that required the most significant changes to planning: (a) moving away from the teaching of content and toward the teaching of research skills; and (b) including connections to new and relevant 21st century science topics. More teaching of both science specific skills and general academic skills is perceived as necessary to meet achievement expectations for students and insure their success on high stakes assessments. A focus on scientific investigation, rather than content, represents a breakthrough in science curriculum emphasis for Scotland, and reflects a trend in science curriculum globally (Achieve.Inc, undated; New Zealand Ministry of Education, undated; Sinnema & Aitken, 2013). Utilizing relevant real-world contexts for science teaching is also seen in other new national curricula designed to reflect 21st century skills (Achieve, Inc., undated; New Zealand Ministry of

Education, undated; Sinnema & Aitken, 2013). Regardless of the individual beliefs of the teachers, their analysis of the impact of these two changes requires that they actively engage in new modes curriculum construction in order for their students to achieve success on exams. That science teachers need to view curriculum standards as guidance for daily aims and lesson plans is certainly nothing new. However, unpacking the implicit purposes and principles relevant to change and choosing to act on these represented a new professional responsibility for Scottish science teachers.

Related to viewing what they needed to teach for student success, and perhaps most dissimilar to traditional thinking, was the shift in the epistemological underpinnings of the document, illustrated vividly by the "I can" language of the achievement objectives. The teachers interpreted this as a requirement to provide students with opportunities to design their own science investigations. As participant Helen pointed out, teaching how to create and apply knowledge is a much different task than teaching a fundamental science concept. Previous global science curricula have been largely authoritative until very recently, albeit with pedagogical opportunities for students to provide some evidence for themselves (Norris, 1997; Osborne, 2014). In contrast, changes to the fundamental approach to science teaching is becoming increasingly investigated by researchers in the global context. One example of this is a project in the U. S. designed to emphasize how scientists come to know what they do, as well as to manage the suite of scientific practices that lead to new knowledge construction. What participants in the Scottish study identified as science specific skills and general academic skills is becoming known as "scientific practices: in the U. S. Berland, Schwarz, Krist, Kenyon, & Reiser (2015, p. 2) describe the new perspective on science learning goals as follows:

> Thus, the emphasis on scientific practices as learning goals and as a pedagogical approach is designed to focus the attention of educators on students constructing

and applying knowledge, rather than on student attainment of discrete scientific and epistemic ideas.

All of the above considerations point to new roles, responsibilities and identities for science teachers in the 21st century arena. Scotland provides a dramatic case of a system which is attempting transformation fairly rapidly. As Humes (2013, p. 18) stated, Scottish authorities are realizing that teacher-designed curriculum development requires a deeper "theoretical understanding of the reconceptualization of professionalism." Previous research on the CfE also suggests that this has been an issue (Priestley et al., 2013) and that many teachers, while welcoming the new curriculum in principle, have not developed deep understanding of the principles and purposes of the new curriculum or what it takes to achieve them. Studies indicated that a tension between the [implicit] theories of knowledge held by teachers and the [equally implicit] epistemological underpinnings of the curriculum has been a particular problem, with implications for curriculum development in practical terms (Priestley, 2011; Priestley et al., 2013). This phenomenon may be particularly evident in the case of less experienced teachers, who have a more limited repertoire of ideas about knowledge and knowing in science than experienced teachers (Priestley et al., 2015).

Implications for policy and professional development

The results of this study indicate that professional development for teachers involved in implementing 21st century curriculum mandates will take much thoughtful planning on the part of school administrators, teachers, and university faculty. There is a call for even more transparency in translating official curriculum documents, although auxiliary text surrounding curriculum standards have introduce some justification and explanation toward this end in the cases of Scotland's CfE and the U. S. Next Generation Science Standards. First, we argue that policy makers provide resources and opportunities with which teachers may come to understand the purposes and principles underlying the seemingly neutral language of curriculum standards (Apple, 2004). Only then, can teachers understand the scope and problem-solving nature of their curriculum development tasks well enough to fully or partially support the innovations.

Second, policy makers need to acknowledge that tensions between and within policies constitute serious barriers to teachers' achievement of agency. For example, in Scotland teachers have been offered autonomy via a reduction in curricular prescription of content or input regulation, as curriculum prescription has lessened, but have simultaneously seen that autonomy eroded through higher the maintenance of high levels of accountability through output regulation, including inspections and usage of assessment data for accountability purposes. It is all very well for policy to demand in statements that teachers become autonomous developers of the curriculum, but achieving this in practice is problematic when systemic issues remain as barriers to such autonomy (Priestley et al., 2015; Nieveen & Kuiper, 2012). The teachers in our study all, to varying degrees, cited the pressures of attainment and other accountability mechanisms as a constraint to their professional agency. This, in turn, raises some significant issues for policy statements; primarily, that there needs to be a consistent message about teachers' agency across different policies. This needs to be combined with a recognition that policy itself, as statement of intent, should not be set out as a detailed recipe for action, but instead should be tailored with the goal of enhancing teachers' agency, through providing cognitive, discursive and relational resources to facilitate teachers' achievement of agency.

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[1] In order for readers to understand some of the findings presented below, it is also necessary to briefly describe Scotland's assessment system that was implemented late in the development scheme and has yet to be completed. For the lower secondary grades (Secondary 1 and 2, equivalent to grades 7 and 8 elsewhere), students are assessed through summative teacher

made assessment instruments and receive pass/fail credit only for particular units of study. For the next level, known as National 4 (Secondary 3 or grade 9), in addition to teacher summative unit assessments, there is also a teacher graded standardized "value added unit" that serves as a capstone assessment for the National 4 qualification. To achieve qualifications at levels National 5, Higher and Advanced Higher (Secondary 4, 5 and 6 or grades 10, 11 and 12), students must pass all units and the value added unit, graded at the level of the classroom teacher, as well as a high stakes paper and pencil exam graded by external markers.

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Appendix A: Examples of Science Achievement Outcomes and Experiences in the Scottish Curriculum for Excellence

Note: The Curriculum for Excellence is divided into five levels ranging from Pre-K to grade 12. Curriculum levels do not specifically correlate with grade levels, as the model provides for flexibility within grade levels. It is up to the teacher to decide at which level to aim her lessons. For example, it is possible some students in S3 would be taught Level Four Objectives.

Level Three- "S1 to S3, but earlier for some [grades 7-9]*" (Education Scotland, undated).* Planet Earth- I can use my knowledge of the different ways in which heat is transferred between hot and cold objects and the thermal conductivity of materials to improve energy efficiency in buildings and other systems. Forces, Electricity and Waves- I can help to design simple chemical cells and use them to investigate the factors which affect the voltage produced. Biological Systems- I have explored how the body defends itself against disease and can describe how vaccines can provide protection against disease.
Level Four- "The fourth level broadly equates to Scottish Credit and Qualifications Framework level 4 [grades 9-12]*" (Education Scotland, undated).* Planet Earth- I have developed my understanding of the kinetic model of a gas. I can describe the qualitative relationships between pressure, volume and temperature of gases. Forces, Electricity and Waves- By making accurate measurements of speed and acceleration, I can relate the motion of an object to the forces acting on it and apply this knowledge to transport safety. Biological Systems- I have taken part in practical activities which involve the use of enzymes and microorganisms to develop my understanding of their properties and their use in industries.

(Education Scotland, undated, downloaded from http://www.educationscotland.gov.uk/)