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Science Teachers' Beliefs and Practices: Issues, Implications and Research Agenda

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The study of teachers' beliefs forms part of the process of understanding how teachers conceptualize their work which in turn is important to the understanding of teachers' practices and their decisions in the classroom. A growing body of research argues that teachers' beliefs should be studied within a framework that is aware of the influence of culture. These studies also argue that teachers' beliefs and practices cannot be examined out of context. This shows that the relationship between teachers' beliefs and their practices is complex and context dependent. Some researchers have found consistencies between teachers' beliefs and their practices whilst others have found inconsistencies. The purpose of this paper is to present an argument about the relationship of teachers' beliefs and practices and to find out frameworks of understanding the consistency and inconsistency of this relationship. In this paper, I explore the nature of teachers' beliefs. Then, I discuss how teachers' beliefs have been formed. Also, I will argue the relationship between knowledge and beliefs. Researchers' key vision of the relationship between beliefs and knowledge was that "whether knowledge directs beliefs or beliefs leads to knowledge. I will argue that the relationship among beliefs, knowledge and practices are intertwined. Then, I present sociocultural perspectives to explain the consistency and inconsistency between teachers' beliefs and practices. I will follow these perspectives by presenting sources of forming teacher's beliefs which will lead to a discussion about potentials of changing teachers' beliefs.

Definition of Beliefs

While beliefs have been described as the most valuable psychological construct to teacher education, they are also one of the most difficult to define since a belief "does not lend itself to empirical investigations" (Pajares, 1992, p. 308). In reviewing the research on this topic, Pajares refers to beliefs as a "messy construct", one that has not always been accorded much precision and which:

> …travels in disguise and often under an alias of attitudes, values, judgements, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertories of

understanding, and social strategy, to name but a few that can be found in the literature (p. 309).

Loucks-Horsley et al.(1998) argued that, "beliefs are more than opinions: they may be less than ideal truth, but we are committed to them" (P. 27). Pajares (1992) also notes that the difficulty in studying teachers' beliefs has been caused by definitional problems, poor conceptualisation, and differing understandings of beliefs structures" (P.307). As has been noted by researchers in other fields, "belief" is not an easily defined concept (Cantu, 2001). Pajares (1992) suggests that studying educational beliefs is in danger of becoming what Nespor (1987) called an 'entangled domain'. As she explains,

> The concept of entangled domain has to do with instances or examples or entities which can be identified by some criteria as belonging to a given domain, but which at the same time do not all share some important sets of criteria and do not fall into relationships of dominance and subsumption with each other. Thematic features overlap only partially and incompletely across domains (p. 325).

Science education researchers have also found this to be the case. Oliver and Koballa (1992) in particular, asked science educators, through questionnaires and interviews, to define the term 'beliefs'. Eight categories were found, some of which included beliefs as being equated with knowledge, beliefs that precede attitudes and behaviour, attributes of beliefs that a person holds true, beliefs as personal convictions based on observation or logical reasoning, and beliefs as an acceptance or rejection of a proposition. Their study indicates that while science educators believe in the important part that beliefs play in the classroom, they are not quite sure what that role is, or how to define it. Moreover, the researchers found a few common elements: (a) the existence of the relationship between beliefs and knowledge; (b) the idea that beliefs are acquired through communication; and (c) a continuum that reflects a range of beliefs from factual to evaluative. According to Siegel's definition (cited in Pajares, 1992) beliefs refer to "mental constructions of experience". Calderhead (1996) also points out the relationship between beliefs and experience and states that teachers' past experiences influence the way they think about their work. To understand thoroughly what is meant by 'belief', it is necessary to understand its nature, as is discussed in the following section.

For the purpose of the present paper, the concept of belief is used to characterize a teacher's idiosyncratic unity of thought about objects, people, events and their characteristic relationships that affect his/her planning and interactive thoughts and decisions. To understand thoroughly what is meant by 'belief', it is necessary to understand its nature, as is discussed in the following section.

Part one: The nature of teachers' Beliefs

There are different views about the concept of belief, depending on the point of view of the theorist or researcher. Dewey (1938) developed a bipolar model within which there were two opposite dimensions: on the one pole, beliefs were characterized as traditional, and on the other as progressive. These two poles formed a uni-dimensional system, since the concept of belief consisted of traditional and progressive components which were negatively related. Thus, a person oriented at the traditional pole would be expected to disagree with progressive ideas and vice versa. Dewey's definition oversimplifies the concept of beliefs and leads to unrealistic understanding of its basic elements (Bunting, 1984). However, since the 1970s, researchers have tried to identify the concept through a multi-dimensional system. Referring to the work of Wehling and Charter (1969) shows that the concept of beliefs is identified as consisting of eight dimen-

sions. Two dimensions describe subject matter and human adjustment matters, while the other six describe instrumental and impersonal processes affecting educational outcomes.

Although Bunting's view is wider than that of Dewey and accepts the fact that individuality and idiosyncrasy do play a substantial role in the development of beliefs, it fails to explain whether a belief component is considered as flexible or stable, and how change can occur within this belief component. Answering this question, Pajares (1992) shows that beliefs are the main component of formulating theories, since they are static and can exist beyond individual control or knowledge. He explains that they are non-flexible because they represent internal truths that remain unchanged in the teacher's mind, regardless of the situation.

However, Rokeach (1968) groups beliefs into five categories according to their connection with central beliefs, and maintains that everybody has beliefs that belong to these five types. Type "A", formed earlier, involves the nature of oneself and one's physical and social world. Beliefs of this type are central. Owing to their connection with societal norms, they are not prone to controversy and thus are hardly changeable. Type "B" beliefs differ from type "A", being private matters and independent of any social judgement. Type "C" beliefs share some characteristics with type "A" beliefs which, to a certain extent, are reshaped through an individual's acculturation, education and schooling. Type "D" involves a group of beliefs that individuals derive from reliable secondary sources such as books and the media. The type "E" beliefs consist of beliefs about taste, which is personal and not to be interfered with. These beliefs are far from the central belief, and rarely connected with the other types. They are not changed and are considered insignificant.

In an attempt to clarify the meaning of "belief", Pajares expresses the need to distinguish between belief and knowledge and explains that knowledge is based on objective fact, while beliefs are based on evaluation and judgment. Supplementary to this is Kagan (1992) who argues that most of a teacher's professional knowledge can be regarded as belief, claiming that knowledge is considered a belief that has been affirmed as true on the basis of objective proof or consensus of opinion.

A further distinction between beliefs and knowledge is that while knowledge often changes, beliefs are "static". In addition, whereas knowledge can be evaluated or judged, such is not the case with beliefs since there is usually a lack of consensus about how they are to be evaluated. Furthermore, there do not appear to be any clear rules for determining the relevance of beliefs to real world events. While there are doubtless other distinctions that could be made between the two constructs, a better understanding may be gained by exploring the relationship between the two, and by considering beliefs as a form of knowledge. This form of knowledge could be referred to as personal knowledge (Nespor, 1987). Kagan (1992) refers to beliefs as a "particularly provocative form of personal knowledge" and argues that most of a teacher's professional knowledge can be regarded more accurately as belief.

According to Kagan, as a teacher's experience in classrooms grows, this knowledge grows richer and more coherent and thus forms a highly personalized pedagogy or belief system that actually controls the teacher's perception, judgment, and behaviour. In terms of beliefs as being personal knowledge, Kagan (1992) states that:

> A teacher's knowledge of his or her profession is situated in three important ways: in context (it is related to specific groups of students), in content (it is related to particular academic material to be taught), and in person (it is embedded within the teacher's unique belief system) (p.74).

According to Nespor (1987), although teachers may have similar scientific knowledge, they are likely to teach in different ways because teachers' beliefs are more powerful than their knowledge in influencing the way in which they teach. The former discussion about the relationship among knowledge, beliefs and practices show a disagreement whether knowledge

forms/controls beliefs or beliefs form/control. Based on an empirical research I have carried out (Mansour, 2008a), there is an interactive relationship between knowledge and beliefs. The settled or developed teachers' beliefs act as an information organizer and priority categoriser, and in turn control the way it could be used. In the interactions between knowledge and beliefs, beliefs control the gaining of knowledge and knowledge influenced beliefs. Now, having discussed the nature of beliefs, it is necessary to focus on teachers' beliefs regarding science teaching/learning, as is done in the following section.

Part two: Teachers' beliefs about teaching and learning science

Researchers often categorize teacher beliefs as either behaviourist (transmissionist) or constructivist. It should be noted from the start, however, that such a dichotomy, while useful in terms of being able to clearly categorize beliefs, may be simplistic and misleading. Theories of learning such as constructivism are so diverse (Ernest, 1994) that it is questionable whether we can possibly categorize sets of beliefs in terms of a behaviourist/constructivist dichotomy. Not only are these theories of learning complex and open to a variety of interpretations, but teachers' beliefs themselves are also complex and sometimes contradictory, and therefore resist a concise classification.

In his review of literature on teachers' beliefs and knowledge Calderhead (1996) summarized beliefs related to teaching and learning. He placed teachers' beliefs into two categories by arguing that some teachers view teaching as a process of knowledge transmission, while others view it as a process of guiding children's learning or as a process of developing social relationships. He also distinguishes between teachers' beliefs based on their experience. Pre-service teachers start with control-oriented belief systems that emphasize the importance of maintaining order and good discipline, and guiding the activities of the children. During training, these attitudes become more liberal and child-centred. However, when teachers enter full-time teaching, they revert to a control-oriented belief system.

Bell and Gilbert (1996) outline two extreme positions concerning the nature of teaching that can take place in a given classroom. The first states that the predominant belief is that the role of a teacher, as an expert in this knowledge, is to present such knowledge directly to students in a logical sequence. The second position is based on the belief that knowledge is constructed by individuals, and that the role of the teacher is to be a facilitator who allows students to reconstruct, extend or replace their existing knowledge. Teachers' beliefs about science teaching are therefore extremely varied. Some teachers believe in teaching students by lecturing or direct teaching. Others reflect constructivist views of learning and teaching, by using co-operative learning or inquiry. However, the majority of science teachers are more likely to mix features of science teaching methods. A teachers' belief about science teaching is more likely to include various aspects of several modes of teaching than it is to fit perfectly into the description of a single model.

Tsai (2002) argues that the beliefs of many teachers, who hold traditional views of teaching science, learning science, and the nature of science, may stem from the problem of their own school science experience. Science classes, laboratory exercises, and relevant activities in teacher education programmes may have reinforced these "traditional" views. In the same way, Trumbull and Slack (1991) believe that teachers fail to develop constructivist-oriented ideas about teaching and learning because they have all experienced success in the existing (i.e. traditional-oriented) educational environments. Therefore, they may not perceive potential insights about constructivist conceptions of learning and teaching.

Teachers' beliefs about learning science refer to their conceptions of the process of learning science, what behaviours and mental activities are involved on the part of the learner, and what constitutes appropriate and prototypical learning activities. The central question of inquiry is:

how and in what way should students learn science? An underlying feature of a particular view of learning, which can be seen to be implicit in some science teaching, has been described by Barnes (1973) as a "transmission view". He describes the teacher who adopts this view as operating a 'speaking tube' down which s/he sends knowledge when s/he asks pupils questions or tells them to write. He considers that it is primarily in order to test whether they have in fact received the knowledge transmitted by the teacher. A teacher who follows a transmission mode as one who:

- Believes knowledge to exist in the form of public disciplines which include con tent and criteria performance. This often means that they see themselves as 'authorities' in a subject;

- Values the learner's performances in so far as they conform to the criteria of discipline;

- Sees the teacher's task to be the evaluation and correction of the learner's performance, according to criteria of which s/he is guardian;

- Sees the learner as an un-informed acolyte for whom access to knowledge will be difficult since he must qualify himself through tests of appropriate performance.

According to Scott (1987), within the "transmission view" a tacit assumption being made by the teacher is that the students do not bring relevant ideas of their own to lessons and that they act simply as recipients of knowledge, adding the information to their "memory store". Thus, chunks of information are transferred from teacher to pupil during teaching.

This view is reflected in a variety of ways: through the teacher's approach to the curriculum, in the type of teaching strategies adopted by the teachers, and in the way students are assessed. As for the "transmission view" of learning, the curriculum is seen as the list of things to be taught. Science is thus presented as a catalogue of "facts". Also, the emphasis is upon "closed" teaching strategies, which support the flow of information from teachers to students. Moreover, the interactions between the teacher and students in the class have the traditional characteristics of the classroom, with the teacher asking a series of closed questions and students playing the game of "guess what teacher is thinking". According to a "transmission view", evaluation of learning emphasizes summative assessment; knowledge has either been transferred or it has not. The teacher is seen as being the active transmitter of knowledge. The pupil is initially empty-headed and plays an intellectually passive role in adopting that knowledge.

As for a behaviourist perspective, the transmission of information from teacher to learner is essentially the transmission of the response appropriate to a certain stimulus. Thus, the point of education is to present the student with the appropriate repertoire of behavioural responses to specific stimuli, and to reinforce those responses through an effective reinforcement schedule An effective reinforcement schedule requires consistent repetition of the material; small, progressive sequences of tasks; and continuous positive reinforcement. Without positive reinforcement, learned responses will quickly become extinct. This is because learners will continue to modify their behaviour until they receive some positive reinforcement (Skinner, 1976). Fox (1983) uses the term "transfer theory" to refer to teachers within the transmission mode. He suggests that teachers who adopt the transfer theory tend to express their view of teaching in terms of "imparting knowledge", "conveying information", "giving the facts", or "putting over ideas". Two of the teaching methods, the lecture and the "chalk-and-talk" approach, represent the classical ways of seeing the transfer or transmission-theory in action (Bentley & Watts, 1989).

In contrast to the transmission view, there is a constructivist view about teaching / learning science. What we call a constructivist approach in science education is a proposal that contemplates active participation of students in the construction of knowledge and not the simple per-

sonal reconstruction of previously elaborated knowledge provided by the teacher or by the text-book (Gil-Pérez et al., 2002). As Hodson (1992) has stated, Students develop their conceptual understanding and learn more about scientific inquiry by engaging in scientific inquiry, provided that there is sufficient opportunity for and support of reflection.

From a constructivist perspective, learning is viewed as the active construction of knowledge in gradually expanding networks of ideas through interaction with others and materials in the environment (Marshall, 1992). The goal of science teaching might be to develop individuals who think for themselves (Newbrough, 1995). Such people have some measures of control over the meaning they make of their experiences, and the ways in which they construct their lives and ideas. Constructivism places primary emphasis on the independence of each person's interpretation of his or her own experience (Roth, 1994). The implications of constructivist views for the science classroom include the ample use of hands-on investigative laboratory activities, a class-room environment which provides learners with a high degree of active cognitive involvement, the use of cooperative learning strategies, and the inclusion of test items which activate a higher level of cognitive processes. Also, the main pedagogical implication is that the active learner's construction of his/her own understanding can be facilitated by teachers who provide stimulating and motivational experiences which challenge students' existing conceptions and involve them actively in the teaching/learning process (Gil-Pérez et al., 2002; Matthews, 1997; 2002).

Within the constructivist view, as mentioned by Watts (1994), science needs to be relevant to students' everyday lives since this real context provides the roots from which their studies should be drawn. It needs to be related to their hobbies and modern lifestyles; to current affairs and television news; to people and practices in the world. Watts (1994) also notes that the move-ment for relevance is not new and that it helped to shape school science in the United Kingdom throughout the 1980s so that schemes like SATIS (Science and Technology in Society) were motivated by the need to relate the "application" of science to current issues in society.

Constructivist teachers of science promote group learning, where two or three students dis-cuss approaches to a given problem with little or no interference from the teachers. In contrast to traditional teachers who see that a given problem has only one solution, constructivist teachers would rather explore how students see the problem and why their paths toward solutions seem promising to them. Constructivist teachers also help students connect their own prior experiences to current situations (Yager, 1995). However, the teachers' roles are different in the behaviourist approach, where a teacher's task consists of providing a set of stimuli and reinforcements that are likely to make students emit behaviour (Yager, 1995). In real science classes, science students seldom see anything they study as having any relevance or applicability in their own lives.

Part three: Relationship between beliefs and practice

In reviewing the research literature, it is noticed that the relationship between teachers' beliefs and their practices was open to debate. A wealth of research evidence has shown that teachers' beliefs about teaching and learning science influence their teaching practices. Through their work with the theory of planned behaviour, Haney, Czerniak, and Lumpe (1996) determined that teacher beliefs are significant indicators of the behaviours that will be present in the classroom. Teachers' beliefs about subject matter have also been found to influence day-to-day decisions about what to teach, what to skip, and how much class time to devote to a particular topic (Cro-nin, 1991).

Pajares (1992) also cites several sources in support of the assumption that "beliefs are the best indicators of the decisions individuals make throughout their lives" (p. 307). He sums up research on teachers' beliefs by suggesting "a strong relationship between teachers' educational beliefs and their planning, instructional decisions, and classroom practices" (p. 326) and adds that "educational beliefs of pre-service teachers play a pivotal role in their acquisition and interpreta-

tion of knowledge and subsequent teaching behaviour" (p. 328). In his view, beliefs are "far more influential than knowledge in determining how individuals organize and define tasks and problems and are stronger predictors of behaviour" (p. 311).

There is still much debate as to whether beliefs influence actions or actions influence beliefs. For example, Pajares (1992) supports the notion that beliefs of teachers influence their perceptions, which in turn affects their behaviours in the classroom. In short, people act upon what they believe. Similarly, Ajzen (1985) suggested that beliefs develop a person's value system that guides life's behaviours. Ernest (1988) also argues that in mathematics, teachers' beliefs have a powerful impact on the practice of teaching during their transformation into practice. In the same vein, Clark and Peterson (1986) described teachers' beliefs and theories as "the rich store of knowledge that teachers have that affects their planning and their interactive thoughts and decisions" (p.258). In this sense, beliefs not only affect how people behave but what they perceive (or pay attention to) in their environment.

Although much research has indicated that teachers' classroom practice is influenced by their beliefs, there is still a need to examine teachers' beliefs in order to clarify how they affect their practice. Beliefs become personal pedagogies or theories to guide teachers' practices: teachers' beliefs play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks. However, some researchers have noted that reflecting on practice can change beliefs. For example, Luft (1999) conducted a study that captured teachers' changing beliefs about problem-solving during an in-service programme. Thirteen teachers in Grades 3 through 6 in a small midestern school district were exposed to a Problem Solving Demonstration Classroom (PSDC) in-service programme for 10 months. They attended a workshop on Search, Solve, Create, and Share (SSCS) problem-solving, and focus groups, interviews, and observation were used to capture emerging beliefs and behaviour changes that were documented throughout the year. In this sense, the relationship between believes and practice is interactive: (a) implicit beliefs became explicit after collaboration and reflection; (b) beliefs and practices were allowed to interact and align; and (c) as the teachers became more aware of their beliefs, they were more inclined to implement the practice in their classroom.

Others have argued that change in belief preceded change in practice (Shulman, 1986). Poulson *et al.* (2001) point out that the relationship between teachers' beliefs and practice is complex, and explain that it is "dialectical" rather than "unilateral"; therefore practice does not always come after beliefs, but may sometimes precede them. In this respect, Carroll (1999) argues that teachers must be involved in the actual development of the STS curriculum so they can build their knowledge concerning STS themes of teaching and learning and reform their beliefs along the way. Teachers must also have the opportunity to develop their views and beliefs about STS. Thirumarayana (1998) too, suggests that before STS instruction can be implemented, teachers must first build upon their interests and use that to develop the conceptual understanding.

Brickhouse, Bonder and Neie (1987) found that one teacher who believed that "quantification differentiates science from non-science" (p. 44) placed "a great deal of emphasis on quantification" (p. 37) in instruction. Another teacher believed that "science is discovered" and used this as a rationale for discovery labs, "which give the students an opportunity to be discoverers" (p. 44). In another study with three secondary teachers, Brickhouse (1990) described how a teacher who viewed theories as truths wanted his students to know about the major scientific theories. A second teacher who considered theories as tools insisted that his students should be able to use them to solve problems. A third teacher viewed "the scientific method" to be a linear and rational process "that leads on unambiguously to scientific truth", believed "scientific procedures to be predetermined" (p. 55), and held that "science activities require following directions to get correct answers" (p. 56). However, research indicates that teacher behaviours are not always consistent with their beliefs. For example, Galton and Simon (1980) indicated that the relationship between teachers' beliefs and their practices was not very strong. As Fang (1996) suggested, there

may be inconsistencies between teachers' beliefs and practices due to the complexities of class-room life, which may constrain teachers' abilities to follow their beliefs and provide instruction that is aligned with their theoretical beliefs. Teachers' theoretical beliefs could be situational and manifested in instructional practices only in relation to the complexities of the classroom.

To sum up, the relationship between teachers' beliefs and their practices are far from straightforward. Beliefs can (a) be contradictory, and compete for priority; (b) have indirect but strong effects on teaching practice, and (c) be often context-dependent, so that they have differ-ing strengths in differing contexts. The following section shows the role of the social context in forming and reforming teachers' beliefs and practices.

Part four: The role of socio-cultural context on forming beliefs and practices

While it has been accepted that the study of beliefs is important to the understanding of teachers' practices and their decisions in the classroom, a growing body of research argues that teachers' beliefs should be studied within a framework that is aware of the influence of culture. other stud-ies argue that teachers' beliefs and practices cannot be examined out of context (Mansour, 2008b), but are always situated in a physical setting in which constraints, opportunities or exter-nal influences may derive from sources at various levels, such as the individual classroom, the school, the principal, the community, or curriculum. The importance of studying this framework is supported by Olson (1988) stated "what teachers tell us about their practice is, most fundamen-tally, a reflection of their culture and cannot be properly understood without reference to that culture" (p. 69). Culture is a screen through which people view their lives and interpret the world around them. It is within this socially constituted nature of culture that beliefs play an integral role in filtering information and determining what is considered important and to be of value in the group.

Lederman (1992) suggests that the transposition of teachers' beliefs into classroom practice is mediated by a complex set of situational variables. Ajzen (2002) suggests that there are many elements that cause a mismatch between beliefs and practices. Real-life factors, such as learner behaviours, time, resources, and course contents, have an impact on the degree of belief-practice consistency. Flores, López, Gallegos & Barojas (2000) assume that the possible reason for such a lack of integration and difficulty in transforming teachers' views into physics lessons is the lack of a systematic and integrated vision about science and learning issues in the teaching of physics concepts. When considering the beliefs of mathematics teachers, Ernest (1988) suggested two reasons why teachers' beliefs did not always match their practice. First there was the powerful influence of the social context that resulted from the expectations of others, including students, parents, peers (fellow teachers) and superiors. It also resulted from the institutionalized curricu-lum: the adopted text or curricular scheme, the system of assessment, and the overall national system of schooling. These sources led the teacher to internalize a powerful set of constraints affecting the enactment of the models of teaching and learning mathematics. The socialisation effect of the context was so powerful that despite having differing beliefs about mathematics and its teaching, teachers in the same school were often observed to adopt similar classroom prac-tices. Secondly, there was the teacher's level of consciousness of his or her own beliefs, and the extent to which he or she reflected on his or her practice of teaching mathematics.

Most of the research indicates that educational beliefs in general and teachers' beliefs in par-ticular are not context-free (Fang, 1996; Pajares, 1992). It is therefore necessary to take into ac-count the contextual factors that have shaped and formed certain beliefs. Thus, researchers must study the context-specific features of beliefs in terms of the connection of beliefs with other be-lief systems and contextual issues (Pajares, 1992). Viewing teachers' beliefs as separated from other belief systems or the broader contextual issues "is ill-advised and probably unproductive" (p. 326). In the same respect, teachers' beliefs and the context in which their beliefs are devel-

oped and used should be taken into consideration in order to have a better understanding of how teaching and learning occur in classrooms and can thus be enhanced. Therefore teachers' own understanding of their work will elucidate how they make sense of their practices and how these perceptions affect their decisions about teaching and learning. Another interpretation is that teachers' beliefs are influenced by the interaction within the nested social contexts within which teachers' beliefs and practices are situated. The similarities and differences in teachers' beliefs might be a product of the different degree of the interaction between the contextual levels and the influence of that interaction on the teachers. What happened in the classroom can be determined to a degree by school policy, which in turn is affected by the educational system and at the most general level, beliefs teaching/learning science.

Teachers' beliefs are knowledge, experience, and environment-based. Teachers are pragmatic, and may establish or validate their beliefs in context-specific environments where their instructional experience is successful. Nespor (1987) explains how the context plays the main role in forming teachers' beliefs: "the contexts and environments within which teachers work, and many of the problems they encounter, are ill-defined and deeply entangled … beliefs are peculiarly suited for making sense of such contexts" (p. 324). According to Nespor, the contexts and environments of teachers' work make beliefs especially potent for defining tasks and organizing the relevant knowledge. Teaching frequently involves dealing with ill-structured problems characterized by a large amount of information, open constraints and the absence of a single correct solution. Indeed, "research on teachers' beliefs suggests that the most significant characteristic of classroom teaching is its many uncertainties" (Kagan, 1992: 79). Nespor (1987) suggested that beliefs are particularly suited to making sense of such contexts because, under such conditions, "many standard cognitive processing strategies … are no longer viable" (p. 325).

From his reading, analysis, and interpretation of the relevant research with teaching contexts, Cornbleth (2001) produced five "climates" or contexts of constraints that he characterized as: (1) a bureaucratic climate with an administrative emphasis on law and order; (2) a conservative climate intent on maintaining the status-quo; (3) a threatening climate of external curriculum challenges and self-censorship; (4) a climate of perceived pupil pathologies and pedagogical pessimism; (5) a competitive climate dominated by student testing and public school ranking. From Cornbleth's point of view, constraints on teachers and teaching are not merely singular or individual as in a single factor affecting an individual teacher. Rather, to understand constraints to meaningful teaching and learning, attention is directed to recurring patterns of contextual constraints that he calls climates, and to how these climates are collectively and interactively created to produce thinking that incorporates diverse perspectives and students. Therefore, the educational systems through a variety of methods (examination system, school inspections etc.) restrict the teachers' professional freedom.

According to the former discussion, the educational system, as a purveyor of knowledge, cannot be separated from the larger socio-economic, political, and cultural contexts in which it operates. Because any society and the educational system it promotes are inextricably linked, the cultural, political, economic, and social structures of society have effects on educational processes and can be regarded as frames. A frame can be anything that limits the teaching process and is ... outside the control of the teacher. The next section gives details about the nature and possible kinds of these mediating factors.

Part five: Mediating factors as a gap between beliefs and practices

The role of contextual constraints on the teaching and learning process has almost disappeared from accounts of educational research. Yet, it is felt and experienced by both teachers and learners in their daily contacts (Gahin, 2001, Mansour, 2007). It is argued that a complete understanding of the process of teaching/learning is not possible without a full understanding of the con-

straints and opportunities that impact upon the teaching/learning process (Mansour, 2008b). Researchers have attempted to explain the mismatching between teachers' beliefs and their practices through the external and internal constrains pressuring the teacher. (Gahin, 2001; Abell, 1990; Abell & Roth, 1992).

Researchers in different fields define common external 'stressors' that affect teachers' performance. These include: work overload, time restraints, and problems with child behaviour, working conditions, relationships with colleagues, lack of resources, and the physical demands of teaching (Borg, Riding & Falzon, 1991; Borg, 1990). Kelly and Berthelsen (1995) identified sources of constraints for teaching practices such as; time pressures, children's needs, non-teaching tasks, personal needs, parents' expectations and interpersonal relationship. A qualitative study carried out by Blasé (1986) with elementary, middle, and high school teachers, emphasized that time was one of the most important constraints and that it could not be understood as independent of the other constraints that were perceived as directly interfering with the instructional time of teachers. Examples were student discipline, student apathy, student absences, inappropriate scheduling, large classes and athletic events. To counteract the time constraints, lecturing and rote memorization were stressed as the main instructional method.

Goelz (2004) mentioned end-of-course tests as a stress factor facing teachers. Such tests force many teachers to maintain a strict schedule that does not allow for creative teaching methods requiring student-generated learning, reflection, and discussion. Muskin (1990) also pointed out that because teachers have to complete all the material required for the tests, they feel obliged to spend very little time on activities that promote constructivist-styled learning. This causes new teachers, who would otherwise like to focus on student-centred learning, to revert to the lecture style that many teachers hesitate to practise but often do. Goelz's research findings (2004) indicate that class size was one of the factors reported among his respondents as having a negative effect on their non-traditional teaching methods.

Using a quantitative study to identify factors that stress science teachers, Okebukola and Jegede (1992) found five clusters of factors inhibiting the effectiveness of science teaching by placing stress on the teachers. These included student characteristics, such as "poor attitude of students to science lessons"; teacher characteristics, such as "having to teach a science subject for which one is not trained"; school environment characteristics, such as "difficulty of obtaining science teaching equipment"; and conditions of service, such as "lack of opportunities for professional improvement." The findings also revealed that the difficulty of obtaining science teaching equipment was the most stressful factor, especially given the experimental nature of the science subject. "The necessity of coping with teaching difficult topics" ranked second on the list of top stress factors, while "difficulty in completing the syllabus in the time available" ranked third. The other two involved "the necessity of coping with the demands of new curricula" and "the obligation to teach large classes".

Maxion (1996) argues that teachers' beliefs are an integral part of classroom practice. When influencing factors (external and internal) complement teachers' beliefs, classroom practice and beliefs are compatible. When these factors interfere with teachers' beliefs, classroom practice and beliefs are disjointed. Maxion (1996) identifies certain external and internal factors affecting teachers' beliefs and practices. The former include life experience, educational experiences, classroom events, school curriculum requirements, students, administrative demands, theoretical knowledge, educational policy, family and peers; the latter include personal practical knowledge, culture, values, and personality and internalized external factors (i.e., positive school experience, life experiences and love of the subject).

In their study of implementing STS education through action research, Pedretti and Hodson (1995) found that working with teachers might not always be sufficient, in itself, to effect significant change in implementing STS curricula. They argue that the structure of the school system – in particular, its bureaucracy, administrative procedures and values – can combine to create and

sustain an institutional climate that is not favourable to, or supportive of, change. They also noted the many occasions when teachers are constrained from implementing a curriculum consistent with their personal beliefs about science and science education due to lack of time, an over-crowded syllabus, inadequate facilities, pressure of external examinations, or class management problems arising from unsupportive administrative structures.

Similarly, Cornbleth (2001) mentions that a bureaucratic school climate with an administrative emphasis on "law and order" is a primary constraint on meaningful teaching and learning. "Law and order" means following school-wide rules (e.g. attendance, dress, homework, grading) and keeping classrooms, corridors and other facilities clean and quiet. It also implies the underlying assumption that centralized order is a prerequisite for teaching and learning. Zeichner, Tabachnick, and Densmore (1987) showed how technical controls such as scheduling, team-teaching, structured instructional materials, and external exams can shape teachers' beliefs and practices in ways that inhibit both teaching for meaningful learning, and critical thinking that incorporates diverse perspectives and students. It seems likely that law and order climates are the product of a mix of personal, bureaucratic, and technical controls.

Abell and Roth (1992) noted that interactions amongst external and internal constraints magnify the negative effect on practice. In the case of one teacher, for example, external constraints presented during the 'rocks unit' still functioned during 'oceans', but did not appear to limit her teaching to any greater degree than before. But the abstract nature of the oceanography content and her lack of knowledge, combined with limited teaching resources, did influence her practice. Their findings of their study showed that change of teacher practices was in response to the subject matter rather than a revolutionary accommodation of teachers' beliefs in compliance with perceived external constraints. In attempting to understand the relationship between external and internal constraints, Otto (1986) insisted that the interaction between them led to stress, and provided a model that described this process of 'stress' as a lack of accommodation between the external demands of the situation and external resources and constraints, and the internal demands of the individual and the internal resources and constraints perceived by the individual.

The research reviewed above indicates that beliefs are context-bound and that social contexts are never static, are implicitly defined, and are ill-structured. Beliefs can neither be clearly defined, nor do they have a single correct clarification. Teachers' beliefs tend to be more experience-based than theory-based. Teachers' classroom approaches to teaching are important referents in understanding their beliefs and knowledge base. Thus there is more than one social factor which can affect or shape teachers' beliefs. These social structures in which teachers work profoundly shape their choices. The following section indicates some sources or the shaping of teachers' beliefs; i.e., how do teachers develop their beliefs?

Part six: Sources of teachers beliefs

Teachers' beliefs are developed throughout their lifetimes and are influenced by a variety of factors, including events, experiences, and other people in their lives (Knowles, 1992). Some beliefs are directly adopted from the culture. Some are shaped by experiences framed by the culture. For example, each individual shares similar experiences as a child, as a member of a family, and as a parent or teacher. These experiences shape their beliefs about students, curriculum development, and overall schooling process (McGillicuddy-De Lisi & Subramanian, 1996).

Shulman (1987) concluded that teachers' beliefs come from four sources: accumulated content knowledge, educational materials and structures, formal teacher education, and "wisdom of practice", i.e., from practical experience. Lortie (1975) suggested that teacher education and classroom teaching experience contribute to the development of pedagogical content knowledge, while disciplinary knowledge in teacher education helps to develop subject matter and curricular knowledge among prospective teachers.

Experience plays a crucial role in shaping teachers' beliefs about teaching and learning processes as individuals in society. As Dewey (1938) noted, personal experience is a key source for education. His criteria for experience to be effective in a person's education were interaction, continuity and wholeness. Mansour (2008b) identifies two types of experience; formal and informal. A formal type of experience is represented in the formal education through which teachers have passed, either at school or at university level, or at in-service training courses. The informal type of experience is represented in teachers' every-day life contacts, past or present, that might have a bearing by adding to, refining, adjusting, supporting, challenging, or even changing their beliefs and knowledge. In this respect, Zeichner (1980) referred to both informal and formal experiences as 'socialisation influences', arguing that teachers' teaching at schools had more power in influencing teachers' beliefs and practices than their formal 'university experience' had done.

Zeichner & Tabachnick (1981) explained that "student teachers become increasingly more progressive or liberal in their attitudes towards education during their stay at the university and then shift to opposing and more traditional views as they move into student-teaching and in-service experience" (p.7). They interpreted this progressive-traditional shift in professional perspectives as a result of students being caught between the conflicting demands exerted by schools and universities. According to this view, the university was absolved of any responsibility in the development of the traditional perspectives that eventually emerged, and the major source of socialisation influence was the schools. This was supported by Cohen (1993) in a review of some British studies, which concluded that when they experienced the impact of full-time teaching students either become increasingly progressive or moved in the opposite direction towards more traditional beliefs. As Zeichner & Tabachnick (1981) concluded "these studies seem to provide overwhelming evidence for the position that the impact of the college is 'washed out' by school experiences" (p. 7).

Zeichner (1980) outlined various explanations for the shift in teaching perspectives with the beginning of school experience. Some reasons for this shift included: cooperation between teachers and others with evaluative power, over student teachers and teachers (Edgar & Warren, 1969), and the bureaucratic norms of schools (Hoy & Rees, 1997). Bartholmew (1976) considered the university experience was the key to understanding the shift of teachers to traditional attitudes when they experienced full-time teaching: "the key is that as a student he never experiences in practice the liberalism which he is so freely allowed to express in theory…the change to conservative attitudes merely expresses what the position was, in practice, all the time" (p. 123).

Experience is seen to filter decisions made by teachers. The kind of experience a teacher has had makes him/her act in a certain manner or conduct a certain classroom activity or even undertake a professional development activity which, in the end, mirrors this experience. At the same time, beliefs have been described as filters through which all new information must pass and which are used to interpret new experiences (Kagan, 1992). In this respect, Pajares (1992) indicates that beliefs are created through a process of enculturation and social construction. Therefore, the incidental learning processes that individuals experience and assimilate during their lives, and all the cultural features they enjoy, become important. Researchers explain that classroom behaviours are the result of beliefs being filtered by experience (Pajares, 1992). In this sense, Butt, et al. (1992) argue that to understand how a teacher thinks, acts, feels and intends, and how a teacher knows what s/he knows, it is essential to understand relationships and tensions in context and a teacher's life experiences. Also, to understand a teacher's classroom practices, the contexts within which s/he works need to be understood.

Thus, even though teachers' beliefs tend to blend into one system and that system is used holistically as an interpretative frame, various sources of teachers' beliefs are still recognizable. They include personality factors, prior learning or teaching experiences, teacher education, teach-

ing contexts, an apprenticeship through observation, and related reading of either research findings or other materials.

Mansour (2008a) revealed that teachers' pedagogical beliefs regarding their roles, students' roles, the aims of science and their teaching methods were strongly shaped by personal religious beliefs derived from the values and instructions inherent in the religion. He found that teachers' personal religious beliefs worked as a 'schema' which influenced what was perceived. McIntosh (1995) defined a schema as "a cognitive structure or mental representation containing organized, prior knowledge about a particular domain" (p. 2). He also noted that schemas were built via encounters with the environment 'social context' and could be modified by experience.

The religious schemas or experiences of these teachers influence the way they perceive new experiences. Teachers arrange the elements of their social context to reflect the organisation of their own personal religious beliefs or religious schemas. A teacher with personal religious beliefs or religious schemas is more likely to force a religious interpretation on experience than a teacher without such personal religious beliefs or religious schemas. Moreover, teachers with particular personal religious beliefs may understand the situation or the experience very differently from those without these personal religious beliefs. However, teachers also hold beliefs about themselves, the nature of science, the individual students, teaching and learning science through STS, the nature of the discipline they teach (e.g. STS issues), the social context in which they live, the school environment in which they work, and the constraints they have to deal with. These beliefs, in turn, work through the lens of past experiences, since they are translated into teacher practices within the complex context of the classroom. However, among all the social factors which might influence or shape teachers' beliefs, the question still remains: can teachers' belief be changed and how? This is addressed below.

Part seven: Perspectives behind change in teachers' beliefs

One common argument in the literature about teachers' beliefs is that changing them is a complex, perhaps even a mysterious process. Beliefs vary in strength, are static (Nespor, 1987), resistant to change (Brousseau, Book & Byers , 1988), and constantly develop over time into a form of system or network which then becomes resistant to change (Block & Hazelip, 1994). However, with the growing awareness of the role and possible effects of teachers' beliefs, a crucial question arises: how can science teachers' beliefs be affected or changed? Kagan (1992) noted that teachers' beliefs seldom change, and suggested that in order to promote professional growth in novice teachers, it would be necessary first to raise their awareness of their own beliefs and then to challenge those beliefs while providing opportunities to examine and integrate new information into their belief systems. However, studies have shown that some individuals change their beliefs based on classroom learning, while others change their beliefs when faced with the reality of the classroom (Veenman, 1984; Joram & Gabriele, 1998; Simmons et al., 1999).

Pajares (1992) provides insight into how beliefs function and how this functioning actually contributes to their resistance to change: beliefs provide personal meaning and assist in defining relevance. They help individuals to identify with one another and form groups and social systems. On a social and cultural level, they provide elements of structure, order, direction and shared values. From both a personal and socio/cultural perspective, belief systems reduce dissonance and confusion, even when dissonance is logically justified by the inconsistent beliefs held by an individual. This is one reason why they acquire emotional dimensions and resist change. People grow comfortable with their beliefs, and these beliefs become their "self" so that individuals come to be identified and understood by the very nature of the beliefs and habits they own. (p. 317).

According to Richardson (1996), "perhaps the greatest controversy in … teacher change is what literature relates to the difficulty in changing beliefs and practices" (p. 110). Pajares (1998)

states that belief changes are difficult and successful only when believers are aware of their beliefs and willing to change them. One strategy, Pajares suggests, is that behavioural changes may lead to belief changes. Believers try to practise against their beliefs, so as to be aware of inconsistencies between their own beliefs and new theories, and to reform their beliefs. He explains the process of changing beliefs; new beliefs do not completely differ from old beliefs, as they include parts of both new knowledge and old beliefs. When these two elements are conflicting, the new knowledge replaces the existing beliefs through the process of "accommodation". Pajares (1992) remarked that beliefs are most easily changed soon after they are acquired and that conflicting evidence is often reinterpreted as support for beliefs that are already held.

Piaget's concepts of assimilation and accommodation can be applied to the understanding of changes in beliefs (Posner et al. as cited in Pajares, 1992). Minor changes in beliefs can be assimilated into the existing belief system. Major changes in beliefs require accommodation. Pajares listed four conditions (p. 321), which must typically exist before students will accommodate conflicting beliefs. First, they must recognize the anomaly. Second, they must believe that the new information should be reconciled with existing beliefs. Third, they must want to reduce the inconsistencies among beliefs, and fourth, they must see that assimilation has been unsuccessful. Pajares noted that this is consistent with the limited success of staff development programmes in changing attitudes and beliefs, unless teachers actually begin to change their practice. "Change in beliefs follows, rather than precedes, change in behaviour" (p. 321) which is consistent with the episodic nature of beliefs.

Richardson (1996) cites several studies where changes in student-teachers' beliefs occurred through socialization and experience but notes that the results of studies of the effects of teacher education programmes were complex. Studies of pre-service teacher education programmes have reported mixed results, some observing changes in beliefs and others not. In-service programmes have generally been more successful in achieving changes and have demonstrated the importance of staff development that affects teacher beliefs for changing instructional practices. She also suggests that the limited success in pre-service programmes might be related to lack of practical knowledge and the difficulty of helping students connect their beliefs to teaching practices. She recommends that additional exposure to teaching contexts through written and video cases, discussions with practising teachers and field work will assist in developing the practical knowledge required for programmes to be successful in changing beliefs. As Bandura (1997) explained, changing or deepening belief systems takes place in one of four ways: experiencing success, observing success, emotional arousal, or through verbal persuasion.

In the literature, studies that explored teachers' beliefs for modelling change in teachers' practices made similar suggestions, despite the differences in the theoretical framework they use. In one study, Tobin and LaMaster (1995) observed changes in one science teacher's beliefs through metaphors, beliefs, and actions, and argued that a teacher's change in beliefs involved more than teacher learning and classroom practices. Teachers need to experience the learned knowledge in a social context to test if this new concept meets their curricular goals. To change their practices, teachers need to become aware of their philosophy of education and their actions in the classroom. They need to reflect why events occur as they do in their classrooms to be able to conceptualize alternatives to practices in the teaching context that are adaptive to efforts to change. Overall, teachers need to be learners and experience their viable knowledge for change in beliefs.

Sikes (1992) points out that teachers are people who can make up their minds and decide what kind of strategy they will use to achieve their purpose. He thus indicates that it is important to understand what imposed changes mean to teachers. He identifies four areas: teachers as people, teachers' aims and purposes, work context and conditions, and work culture. However, once a system of beliefs becomes established, there are several stabilizing characteristics that must be dealt with if change is desired. The first is centrality of belief. Several researchers have found

that the more central a belief, the more it will resist change (Rokeach, 1968). There is evidence (Pajares, 1992) to support the claim that beliefs are held in clusters and that some are more central and resistant to change. The separation of clusters of beliefs may be such that it is possible for a person simultaneously to hold conflicting beliefs: "Clusters of beliefs around a particular object or situation form attitudes that become action agendas" (p. 319). Only when circumstances bring both clusters of belief into play does the dissonance become apparent and require resolution.

From the professional development view, Borko and Putnam (1995) argue that current educational reform recommends a shift toward a student-centred paradigm. This entails a substantial departure in teachers' approaches from a traditional transmission of knowledge to a cognitive and social construction of knowledge. The development in beliefs occurs in the stages after students have experienced both theoretical and practical components of the course and reflections on changes appear to occur mostly during the university-based components. It was concluded that both university and practice teaching experiences contributed but that reflection was more likely to be possible in the periods when the time pressures of practice teaching were reduced. In a study of four pre-service elementary teachers,

A meta-analysis by Wilson, Floden & Ferrini-Mundy (2002) found that pre-service biology teachers found it difficult to express the interrelationships among the topics they had learned and could only list them as courses they had taken. However, with a year of pedagogical training and field experience, they "began to reorganize their knowledge of biology in the light of how it should be taught" (Wilson, Floden & Ferrini-Mundy, 2002, p. 194), which led to a more complex understanding of the relationship between learning goals and instructional strategies. In another attempt to investigate the changes in physics teachers' epistemological and learning conceptions, Flores, López, Gallegos & Barojas (2002), designed a Specialisation Programme in Teaching Physics (SPTP) as an in-service teacher course. The findings of their study indicate that it is possible to make a gradual rather than a radical modification between close positions. For example, it is possible to perceive a consistent transformation of teachers' views from empiricism and behaviourism towards intermediate positions (logical positivism and cognitivism), whereas passing from empiricist and behaviourist positions towards constructivism implies a difficult and complex transformation.

Part eight: Implications

The paper identified a variety of significant implications for science education. These included science teacher education, science curriculum development, and conducting educational research in science education. The implications suggested that all people involved in the educational system needed to engage in thoughtful reflection and discussion about developing science education.

Implications for science teacher education

In terms of science teacher education, the focus on teachers' beliefs in this study carried the potential for improving teacher education in many ways, including the following:

- Not all teachers' beliefs turn into practices. From the teachers' viewpoints, there are many factors that act as barriers for teachers to put their beliefs and frameworks for action into practice. These barriers are identified, as was the mismatch between the teachers' expressed beliefs and their observed practices. Teachers' beliefs are mainly influenced by types of constraints which Ajzen (1988, 2002), in his 'theory of planned behaviour', called 'perceived behavioural control' or 'perceived control over the performance of behaviour'. Therefore, to enable

teachers to attempt to resolve inconsistencies between their beliefs and practices, science teacher educators should help teachers to find ways of thinking creatively about these constraints and to use coping strategies with such constraints. The relevant authorities, in Education, should also consider minimizing some of the constraining factors. Possible ways to do this include changing the emphasis of the educational system from an examination-orientation to a learning–orientation.

- Identifying particular individual beliefs may assist in a better understanding of belief systems in general and their often inherent contradictions. Understanding individual's beliefs can help identify those beliefs, which may be more central to a particular learning theory. On a practical level, an understanding of individual's beliefs can assist in the design of professional development sessions.

- The paper provides science teacher educators with insights into how teachers view their professional roles. This will help them determine the types of experiences that are important for these teachers as they enter the profession. The study showed that teachers alone cannot be responsible for the quality of their classroom practices. External contextual factors can be a barrier for teachers in putting their theories into practice. These constraints are socially constructed and can be modified, if not deconstructed and reconstituted.

- The interaction among experiences (e.g., teacher preparation programme, teachers' life-in-school experiences, "past school experiences", teachers' life-out-of-school experiences and religion is a significant factor in understanding the relationship between teachers' beliefs and practices and how such experiences can shape teachers' identities, and in turn affect their orientations and practices in class. So, understanding the experiences of in-service or pre-service teachers and exploring their identities will be an important activity for teacher education. In this way, we can understand how we can deal with their experiences or identities and channel them into contributing to more development.

- Teachers had a fairly coherent set of pedagogical beliefs which to some extent predicted their instructional practices. Inquiry-oriented and constructivist teaching appeared to conflict with more traditional beliefs about the nature of science and some aspects of science teaching and learning. Therefore, the beliefs of many science teachers may need to be changed to achieve a broader implementation of the strategies that are coherent with constructivisit philosophy. But how can this be achieved?

Implications for decision makers

- When making decisions regarding class size, the tendency of government and decision-makers is to focus on cost considerations, influenced first and foremost by funding availability and local fiscal priorities. In doing this, they may not sufficiently take into account considerations of education quality. To counter this, the teachers should be trained to be able to deal with large number of students and at the same time serious efforts should be made to reduce class sizes. Galton et al. (1996) point out that currently there does not appear to be much preparation in initial teacher training concerning ways of adapting to class size.

- Teachers have always argued for good working conditions to implement STS, because they know from experience that good working conditions foster an environment that produces good learning conditions. The conflicting priorities regarding the issue of class size call for a balanced outcome. In order to ensure such an outcome it is important to take into account the interests of all parties concerned – students, teachers, parents, and decision makers.

- While teachers are particularly concerned with the quality of education and implementing constructivist views, other stakeholders may have different priorities. A balance is required that addresses the concerns of everyone involved by reconciling competing interests. Also Teachers' voices should also be heard and taken account of concerning the practical problems they face when they implementing any new ideas.

- Teachers perceived the principal sources of constraints as 'external', and felt that most, if not all, of the decisions related to their careers came from outside in a 'top down' manner. This raises the question of why teachers feel this way. A possible answer is that since teachers do not contribute to any decisions regarding curriculum development, teacher training, teacher preparation, etc., they do not feel obliged to take responsibility for any changes or innovations. Decision makers should consider teachers' views when they implement changes related to the educational system.

Implications for science curriculum development

In terms of science curriculum development, the following points can be summarized:

- The argument in this paper may draw the attention of decision makers and curriculum developers to the fact that teachers do not passively accept innovative ideas once they have been informed about them, or unless they are convinced of their effectiveness. In this respect, Yager (1991, p. 91) maintains that the central failure of any "fundamental reform" in science education is primarily the responsibility of teachers "because they are major forces for maintaining the status quo in the curriculum." In this respect, Vulliamy, Kimonen, Nevalainen & Webb (1997) argue that curriculum changes are rarely implemented as originally intended but instead undergo a process of 'mutual adaptation'.

- The paper offers the curriculum developers an insight into the important effect of teachers' beliefs on the development of the science curriculum. As McLaughlin (1987) has pointed out, "what actually is delivered or provided under the aegis of a policy depends finally on the individual at the end of the line…" (p. 174). Central to the realization of any curriculum implementation goal is the need for information concerning the beliefs that teachers hold about curriculum implementation and the origins of these beliefs. Research supports the idea that teachers are crucial change agents for educational reform and that teachers' beliefs are precursors to change.

- This paper showed how the setting or environment of classroom teaching and learning can influence what is taught – the context powerfully shapes STS teaching and thus affects students' opportunities to learn. The current study agreed with the argument of that the focus of curriculum reform efforts ought to be on planning for

desired curriculum practice. Therefore, attention ought to be paid to creating conditions supportive of STS curriculum practice, as well as designing the practice itself. This involves creating conditions which recognize the constraints involved, and finding ways of addressing them.

▪ This paper showed the effects of the school administration and the science supervisors on the inconsistency between teachers' beliefs and their practices. Providing considerable freedom to teachers to make instructional decisions helps them to match their beliefs and their teaching practices. The study concurs with McNeil (1986), who concludes that efforts to improve schooling (or teaching and learning) by means of regulations, accountability measures, or other controls – what Cornbleth (2001) calls a "law and order" climate – have the effect of encouraging traditional approaches to teaching and undermining meaningful learning and critical thinking that incorporate diverse perspectives and students. This implies that the administrators should give teachers more support and more freedom to be able to create teaching environments conducive to the ideal science teaching, leading to scientific literacy and understanding of the social and technological implications of science.

Part nine: Future research

There is a need to identify the beliefs brought by in-service or pre-service science teachers to their teacher education programme about teaching and their role as the teacher. What do science pre-service teachers remember about their prior schooling experiences? Why do they remember these events or people? Do their interpretations of religion influence how the teachers see themselves? As Pajares (1992) argues, it would be useful to explore the effects of these beliefs beyond the pre-service experience. Therefore, there is a need to examine the religious beliefs of pre-service science teachers and the influence of these beliefs about teaching science. Research on the educational beliefs of pre-service science teachers may also help reveal how they interpret and define the goals and curricula of a teacher education programme from religious perspectives. Future research is required to go beyond understanding the beliefs of pre-service or in-service teachers and move towards changes in teachers' beliefs and how these affect their students' developing understanding.

The paper has raised questions regarding teacher educators' roles in developing teachers' knowledge, beliefs and practices, as well as questions about teacher educators' roles in changing teachers' beliefs and practices. A number of researches argue that any process of change in teacher education needs to be cognizant of the motivations and attitudes of teacher educators themselves (Robinson & McMillan, 2006; Welmond, 2002). Internationally, there has been a lack of attention to research on teacher educators (Robinson & McMillan, 2006). Therefore, this calls for research that focuses on teacher educators' beliefs and views concerning their personal practical knowledge of teacher education programmes.

The paper highlighted the role of personal religious beliefs and experiences in understanding teachers' beliefs and practices. However, there is still a need for a deep understanding of how teachers, through experience in both their private lives and their professional contexts, have acquired these religious beliefs. This can be answered through biographical inquiry, a research approach that enables sense to be made of teacher's individual experience and religious beliefs.

The paper highlighted that the life experiences of teachers play a major part in contributing to the formation of their beliefs, and also influence their practices. Because teachers' experiences change daily, it is assumed that their beliefs and practices will also change; therefore, it is imperative to examine the nature of that change. Moreover, if teachers experience change in their

beliefs and practices about teaching and learning science in a way that is consistent with the philosophy of a particular model of change, then it is crucial not only to examine the nature of that change, but also to examine the model that motivated the change (including teachers' beliefs about that model) and to describe and identify factors that facilitated change.

Also, in order to develop an effective science teacher education programme, we must identify not only the presence of change, but also teachers' beliefs about their change. From this perspective, beliefs are a practical indicator, providing a good estimation of teachers' experiences and establishing the framework for future teacher professional development. So, to arrive at the model that has motivated the change in teachers' beliefs and practices, it is necessary to carry out a longitudinal study with pre-service and in-service science teachers. Also, there is a need to undertake an in-depth discussion about disciplinary influences on the beliefs and practices of the teachers, so that there is a need to investigate the beliefs and practices of teachers who are specialists in different disciplines.

It was evident that teachers regarded school textbook content to be one of the reasons for students' distress. There is a need to explore the social construction of the school science textbooks. Such an investigation will provide an important context within which to examine critically the dynamics underlying the cultural politics of science education and the social movements that form it and which are formed by it. Understanding science curricula through the forms in which they are publicly presented requires identifying, analysing and critiquing their building sequence through investigating the work of authors, editors, publishers, teachers and students as they struggle to create meanings.

Finally, the paper showed that there were certain people with whom teachers dealt during the educational process, e.g., the school administration and science inspectors, educational decision makers and their aims, the family, and the learners themselves. Since all these people affected teachers' beliefs and practices in one way or another, there is therefore a need to investigate the role played by the beliefs of faculty/staff, administrators, principals, and student' parents.

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