sciendo

DOI: 10.2478/cdem-2019-0006 CHEM DIDACT ECOL METROL. 2019;24(1):77-87

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IMPORTANCE OF TEACHERS' BELIEFS IN DEVELOPMENT OF SCIENTIFIC LITERACY

ZNACZENIE PRZEKONAŃ NAUCZYCIELI W ROZWOJU KOMPETENCJI NAUKOWYCH

Abstract: Science teachers communicate curricula goals to their students, prepare teaching situations and lead their students through them in order to learn science. The purpose of this study was to identify the beliefs of teachers about teaching and learning, specifically, what the teachers focus on, how they comprehend knowledge and their role in the process of learning since they can promote or hold back development of scientific literacy. Q methodology was used to investigate the beliefs of 65 science teachers by having them rank and sort a series of 51 statements. Factor analysis was used to identify identical patterns. The analysis showed that the teachers held four types of dominant beliefs about the effectiveness of science instruction and some common feature which have potential to influence educational process. Teachers concentrate on covering the content even if they declare the importance of personal construction, feel responsible for students' learning and its outcomes. Despite stressing the activity of the students, the teachers did not emphasize particular science process skills and scaffolding process. The findings of the study suggest that systematic trainings focused on the nature of science and the scaffolding process would be beneficial for teachers in all identified factors.

Keywords: scientific literacy, curriculum, teachers' beliefs, Q methodology

Introduction

The development of society has placed different demands on the knowledge required of students. Curricula intend to prepare scientifically literate people who can understand the surrounding world and process how we get to know it e.g. [l-4].

Inquiry-based learning (IBL) has proven effective in improving the science process skills (SPS) of students [5-7], their understanding of conceptual knowledge [8, 9]; and general student achievement in science [10]. IBL has proven effective in changing attitudes toward science [7, 11], increasing the students' understanding of inquiry processes [12, 13], and increasing their motivation to learn about science [l4]. Research shows that students are able to transfer their argumentative skills from the given subject matter to everyday problems and apply these skills in order to solve them [l5]. Such learning increases the pupils' understanding of how scientific knowledge is generated [l6, 17]. IBL cannot be

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disconnected from the nature of science, since understanding is an essential part of scientific literacy [18].

Teachers' role in developing scientific literacy

The success in reaching the goals expressed by the curricula depends on the teachers' understanding of and belief in them [19]. The ongoing demand to improve science teaching and learning due to unsuitable outdated methods of teaching and learning science [20, 21] requires a shift from teacher-directed teaching to a student-centred classroom with an inquiry-oriented approach. This approach requires dialog, questioning, argumentation, etc. [22]. However, teachers find these changes to be difficult [23, 24]. Even when they are explicitly asked to make a change in the goals, they do not always effectively communicate this in their scientific practices [25, 26].

Research shows that teachers do not always understand what is asked of them and interpret new requests as pure adaptation to what they have already been doing [25]. Any activity of students in the science class is considered to be a change demanded by the curricula. Facilitating, inspiring and awakening the curiosity of students are mixed with giving information beforehand or by immediately correcting any, even potential, mistakes made by the students. This kind of pedagogy illustrates primarily teacher-centred teaching [27]. Teachers seem to be selective in choosing recommended forms of teaching based on their familiarity with their previous practice [28].

Studies show that teachers lack confidence in their own scientific knowledge and skills [29], and they hold on to their beliefs [30], which represent internal obstacles to fulfilling curricular goals. External problems are lack of time, unsatisfactory classroom conditions, unsuitable and infrequent types of assessment or lack of community support [31, 32]. Other factors influencing the beliefs of teachers and consequently affecting their practice in the class are the knowledge of the teachers about scientific concepts, the nature of science and the pedagogical content knowledge, the prior experience of the teachers, the type of assessment, school resources, the amount of time allotted for science, parental involvement [33], student behaviour and ability [34] or the reflections and conclusions teachers have made about classroom outcomes [35]. Paying attention to the beliefs of teachers seems to be crucial since they represent rather strong predictors of the actual practice in the class [36].

Research questions and methodology

Science teachers are the ones who communicate the science curricula goals to their students, who prepare teaching situations and lead their students through. However, it is not clear how science teachers adapt and understand the goals set in science curricula in the first place. Therefore, we have focused on 4 areas concerning the beliefs of teachers and have formulated the following questions:

- Do science teachers concentrate more on science content or on the process of how their students learn?
- Do science teachers help to develop science process skills or primarily try to build their students' knowledge based on pure facts and laws?
- Do science teachers help their students build their knowledge through argumentation or communicate the knowledge as something stable and unchanging?

- Does a science teacher represent a searching person or a source of correct knowledge for his/her students?

Q methodology was used to identify the beliefs of science teachers about the processes and goals in science education. The aim was to reveal the subjective belief structures of participating teachers [37]. In Q methodology, a collection of representative statements is selected (the Q sample). Participants were asked to sort the statements by ranking them based on what is the most and the least relevant in their teaching practice (Q sorting). The indicated number of statements were assigned to each ranking position. In order to stress their beliefs, the participants assigned the highest and the lowest values on the scale to a limited number of statements (Table 1).

Table 1

Q-sorting distribution

Value of the statement										
–5	–4	–3	–2	–1	0	+1	+2	+3	+4	+5
1	2	3	5	8	13	8	5	3	2	1
Number of statements assigned to ranking position										

Such sorting showed what is strongly agreed upon and preferred and what is strongly rejected. The statements placed in the middle of the scale indicate a neutral position which means the participant regarded them as being less important or having no importance at all.

The Q sort consisted of 51 statements covering 4 areas of research interest. Each area was composed of 6-7 pairs of statements expressing constructivist and transmissive points of view. One statement (No 51) represented the influence of external element on science education, specifically money [38].

In Q methodology, the respondents (the P sample) are obtained by strategic sampling in order to ensure comprehensiveness and a diverse range of viewpoints, rather than representativeness and quantity. Q methodology tries to identify existing subjectivities. It does not concentrate on learning how that subjectivity is distributed across a population [39].

The study used a sample of 65 science teachers from lower secondary school. They had varying degrees of teaching experience. Women in the sample outnumbered the men (with only 17 of the 65 teachers being men). None of them had attended any training focused on constructivist views on learning, development of SPS, argumentation, etc. However, some of them had tried project-based teaching, team-teaching and other methods and approaches. Teachers came from various school types (public, parochial, private).

Once the Q sort was complete, the data was analysed by creating a correlation matrix for the factor analysis, which provided clusters of similarities among the participants' responses [39]. The factor scores were calculated based on statistically-objective criteria. The Z-score shows the extent to which the statement deviates from the distribution mean (0) and the direction of the deviation. The Q-sort values (Q-SV) are based on the rank ordering of their factor Z-scores; the statements are sorted for each factor into Q-sort slots from –5 to +5. We used the PQ Method to analyse the data [40]. The program fulfils the requirements of Q studies. It computes inter-correlations among Q-sorts, which then undergo factor analysis by a centroid method. The resulting factors are rotated analytically by Varimax rotation. Relevant factors based on their eigenvalues and the numbers of Q sorts loading on factors were selected. The standard requirements for the selection of factors for interpretation are an eigenvalue exceeding 1.00 and at least two Q sorts loading significantly on that factor. The significance of these statements is at $p < .01$ and $p < .05$.

Results

The analysis found four types of belief sets among science teachers stressing, ignoring or rejecting different aspects in science teaching. The revealed factors explained 51 % of the study variance which is considered to be a sound result [41]. Factor 1 consisted of 20 teachers explaining 21 % of the variance, 7 teachers were grouped in Factor 2 explaining 11 % of the variance, 2 teachers in Factor 3 explaining 7 % of the variance, and 5 teachers in Factor 4 explaining 12 % of the variance (Tables 2 and 3).

Table 2

Factor characteristics

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Eigenvalue	14.28	7.48	4.76	8.16
Cumulative percentage [%]	21	32	39	51
Composite reliability	0.99	0.97	0.89	0.95
S.E. of factor Z-scores	0.11	0.19	0.33	0.22

Distinguishing statements for the particular factor were based on a significantly different placement of the statements compared to three other factors ($p < .01$, $p < .05$). The analysis also takes into consideration the statements to which extreme values (*Q-SV* = 5, 4, –5, –4) and neutral values (*Q-SV* = 0) were assigned.

Three identified factors (Factors 1, 2 and 4) stressed the importance of a constructivist approach in science education. The teachers who loaded on Factor 3 stressed the transmissive approach. Factor 1 shows the biggest gap between constructivist and transmissive statements (Table 3).

Table 3

Average Z-score for inductive and deductive statements in identified factors

Statements	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
Z-scores of constructivist statements	0.82	0.09	–0.01	0.44
Z-scores of deductive statements	–1.27	0.06	0.35	–0.46
Difference	2.09	0.03	0.36	0.02

Factor 1 Teachers as providers of active learning

There were 15 women and 5 men in Factor 1. Their teaching experience ranged from 2 to 25 years. The statement with the highest agreement ($Z = 1.75$) described learning as a dynamic activity where students discuss the studied issues, present evidence and confront each other. They highly disagreed that students cannot think hypothetically ($Z = –2.30$). Distinguishing statements for teachers loading on Factor 1 revealed the importance of students being active ($Z = 1.75$, *Q-SV* = 5) by searching for evidence and using argumentation when learning new concepts ($Z = 1.36$, *Q-SV* = 3). Teachers disagreed that their role should be providing non-contradicting facts ($Z = –1.29$, *Q-SV* = –3), which strengthened their belief about effective learning as expressed above. They feel rather indecisive when it comes to the assessment of the topics learned or understood. Students not having an argument to support the given statement might or might not understand the studied topic (*Z* = –0.32, *Q-SV* = 0). Teachers grouped in Factor 1 consider the gradual development of student knowledge as important (the constructivist area 3 statements) without particularly stressing the importance of the development of SPS (the constructivist 2 area, *Q-SV* = 2). They refuse to regard their role as providers of information who should not evoke discussion or stimulate suggestions. They do not see themselves as sources of correct and secure knowledge for their students (the transmissive 4 area, *Q-SV* = –3). They did not particularly specify the goal of science education (area 1 statements *Q-SV* ranges from 1 to –1).

Factor 2 Teachers as a guarantee of correctness

Seven teachers, 1 man and 6 women, loaded on Factor 2. Their teaching experience ranged from 6 to 21 years. They agreed the most that students learn the best when they discuss and formulate questions about the issues being studied (*Z* = 2.32, *Q-SV* = 5). Teachers commonly disagreed the most that students learn the best by observing a teacher or by studying textbooks (*Z* = –2.30, *Q-SV* = –4). They see their role as guarantees of understanding, and they say they explain the given issue if the students do not understand it correctly (*Z* = 1.31, *Q-SV* = 3). They did not agree with the statement that students at the primary level should learn only the basic facts and omit discussion since this is suitable solely for a higher level of science education (*Z* = –1.99, *Q-SV* = –4). According to them, it seems obvious that students should learn facts and laws (*Z* = 0.30, *Q-SV* = 0).

Factor 2 teachers stress dynamics and change in developing knowledge while learning (the constructivist 3 area, *Q-SV* = 5). They disagree that basic science facts would be sufficient (the transmissive 3 area, *Q-SV* = –4). They see their role as guardians and providers of correct understanding (the transmissive 4 area, *Q-SV* = 3). They do not seem to be sensitive to the development of skills which enable students to find arguments and use them in valid discussions as mentioned above (the constructivist 1 area, *Q-SV* = –1). Learning verified facts in science seems to be matter of course (the transmissive area 1, *Q-SV* = 0). These teachers disagree that the starting point for learning can be found merely in observing a teacher and studying the textbooks (the transmissive 1 area, *Q-SV* = –4).

Factor 3 Teachers who approve of inquiry but do not recommend it for their students

Two female teachers loaded on Factor 3. They were in their 50's and had 30 and 32 years of teaching experience. They agreed the most that students create their own understanding about the phenomena studied by doing inquiries and working with various information (*Z* = 2.04). They highly disagreed that effectiveness could be reached by telling students what to do and what to learn (*Z* = –2.33). The teachers in Factor 3 see their students as not being able to present arguments and consequently lead a meaningful discussion (*Z* = 1.75, *Q-SV* = 4). They significantly disagreed that learning starts with the teacher's explanation (*Z* = –1.81, *Q-SV* = –4). Receiving help from the teacher and work with textbooks seem to be considered as a common praxis (*Z* = 0.29, 0.00, *Q-SV* = 0).

The teachers who loaded on Factor 3 believe that the focus should be placed on the process, precisely on the work of active inquiry which makes knowledge more stable, instead of students merely learning verified content in science education (the constructivist 1 area, *Q-SV* = 5, 4, the transmissive 1 area, *Q-SV* = –4). However, these teachers are convinced that students still should be provided with the basic knowledge (the transmissive 2 area, *Q-SV* = 3). The teachers in Factor 3 seem not to consider their students to be able to fully comprehend the development of scientific knowledge (the transmissive 3 area, *Q-SV* = 4, the constructivist 3 area, *Q-SV* = 3). They do not particularly stress their role as a teacher.

Factor 4 Teachers of curious students helping to construct correct knowledge

Four women and one man loaded on Factor 4. Their teaching experience ranged from 5 to 20 years. The highest Z-score was assigned to the conviction that knowledge learned by doing activities of inquiry is more stable than learning otherwise (*Z* = 2.31). The lowest Z score was assigned to the statement that rejected the idea of textbooks as an important source of information (*Z* = –2.47). The teachers loading on Factor 4 particularly stressed that learning is an active individual process when a student constructs new meaning from what he/she has read, heard or experienced (*Z* = 1.76, *Q-SV* = 4) and that it is important that students ask meaningful and relevant questions about the phenomena studied. They see student curiosity as an important factor in developing knowledge (*Z* = 19, *Q-SV* = 4). Textbooks do not fulfil this function, and therefore these teachers do not consider work with them as important (*Z* = –2.47, *Q-SV* = –5). These teachers feel neutral about the idea of them explaining issues, discussing with students or even doing inquiry (*Z* = 0.48, 0.21, 0.18, *Q-SV* = 0).

The teachers loading on Factor 4 comprehend learning as an individual personal process revising what the students have experienced, read or heard (the constructivist 1 area, *Q-SV* = 4); however, this does not necessarily mean constant learning or systematic inquiry (the constructivist 1 area, *Q-SV* = 1 and 0 respectively). These teachers do not consider teaching how to use a textbook as something important (the transmissive 2 area, *Q-SV* = –5), but other than that they do not stress any skills which should be learned as a part of science education. It is important for these teachers to keep their students curious and keep them asking questions, which they see as an important sign of effective learning (the constructivist 3 area, *Q-SV* = 4). These questions indicate how the student thinks and help the teacher to learn about the reasons for their misconceptions (the constructivist 4 area, *Q-SV* = 3). These misconceptions need to be corrected by the teacher (the constructivist 4 area, *Q-SV* = –3).

Consensus views

We have identified views common to all four Factors. Consensus statements are those that do not distinguish between any pair of factors (Table 4).

Table 4

Correlations between Factors

Factor	**1**	**2**	**3**	**4**
1	1.00			
2	0.63	1.00		
3	0.24	0.29	1.00	
4	0.68	0.67	0.20	1.00

Teachers in all 4 factors consider it obvious to work with a sufficient amount of information coming from reliable sources. They take it to be obvious that they need to correct students’ knowledge by providing opportunities to prove that they are wrong.

The teachers use common methods of explanation; they do exercises and solve various tasks connected with the topics studied. They all agree that the goal of science education is to provide basic knowledge in the form of facts which students can use in the future.

Discussion and implications

The correlation among Factors 1, 2 and 4 shows rather homogenous groups of teachers explaining 44 % of the variance. Teachers loading on these factors have mostly constructivist views on teaching and learning. The finding suggests that these teachers would be able to help their students to achieve scientific literacy. They want their students to be active. This activity might take on any number of forms in the science classroom (mental, hands-on activities, collaboration, etc.). This suggests that teachers feel an urge to actively involve their students more in the learning process and that this is becoming part of their belief structure. It is important that despite holding some transitional views, these teachers might give their students a chance to construct their knowledge and encounter information which might serve to create or correct it. The teachers in these factors show some signs of behaviour typical for a transitional and responsive set of beliefs as described by Lewitt [42]. The transitional teacher creates a classroom environment that cognitively involves the student, and the teacher focuses on the students' understanding by concentrating on content. Responsive teachers are student-focused and design the classroom environment to enable students to interact with each other and their knowledge. Students have a chance to hypothesize, share, create and question in small groups and thus create their own understanding. This is a rather promising finding, especially in Factor 1, in the sense that it might fulfil the goals of the curricula and requires student-based teaching [25], even though the teachers do not point to the development of any SPS or inquiry. The development of these skills requires special attention and does not seem to be used easily and intuitively. Even experienced teachers using inquiry teaching in their classes regularly struggled with argumentation [43].

The teachers in Factor 1 refuse to provide non-contradicting facts to their students emphasizing their position as facilitators for learning, which Lewitt [42] also identified as one of the dominant emerging beliefs from teachers' responses. This role requires a guiding critical evaluation of information or data gained from various resources (or perhaps the students' own inquiry), argumentation, and meaningful drawing of conclusions - things with which teachers usually struggle [43]. Reid et al. [44] describes guidance as interpretative, experimental and reflective, which the teachers who loaded on Factor 1 did not express at all.

The teachers in Factor 2 still feel that they are in charge of what the students learn, and they feel a sense of responsibility for the outcomes. If active learning is "not working" and the student does not understand the concept correctly, these teachers simply "transfer" correct knowledge by explanation and in that way correct the students' knowledge. They represent a blending of a teaching-centred and learning-centred orientation [45]. They give (or want to give) students a chance to develop their expertise, but if their understanding of the concept is not correct, the teachers provide this understanding. Teachers are in control of the content. Their conception of the teaching model, according to Boulton-Lewis et al. [46], could represent "teaching as developing students by providing opportunities, experiences and activities" mixed with "teaching as developing students' understanding by providing, structuring, guiding, etc." Such beliefs raise questions about how these teachers comprehend student learning. Conceptual change takes place only after a sense of dissatisfaction is experienced with the prior conception and the discovery of an intelligible plausible and fruitful alternative [33]. Pure explanation also doubts the student-centred teaching. If a teacher is not open to students making mistakes, a shift from teacher-centred teaching is not likely to happen [27]. Lazonder and Harmsen [48] add that although the results show a better performance of students in guided rather than in unguided inquiry, nonetheless guiding actually means stimulating the students' sense of responsibility for their own learning which is an important element in inquiry-based science instruction [8].

Teachers often diminish the cognitive demand of goals embedded in curriculum materials [49]. The dominant transmissive views of Factor 3 teachers with long teaching experience suggest that they are comfortable with their ways of teaching without giving any chance to a method where the teacher plays a less dominant role. They have arguments for why they want to stick with their old ways of teaching, their students cannot do better. Another explanation could be found in their conviction that the goal of science education is to provide students with basic knowledge about natural phenomena, which only a teacher can correctly and adequately communicate to students. According to Samuelowicz and Bain [45], these teachers oriented towards the teacher-centred approach expect a reproductive understanding of knowledge which was transmitted to them. Boulton-Lewis et al. [46] describe this category of conceptions about teaching as the transmission of content where the teacher and the content are more important, and students remain in the background. However, the way in which teachers in Factor 3 comprehend learning does not correspond entirely with the concept Boulton-Lewis et al. describe. Factor 3 teachers claim that learning is not only about the acquisition and reproduction of content, but it is also about the development of understanding. However, the process of learning is ignored by them.

Teachers loading on Factor 4 consider curious students who pose various questions as important and meaningful in science education. However, they expect constructing correct knowledge at every stage of development. The stress is therefore put on the content and outcome instead of on the process of constructing the concept. The process of how students build their knowledge might not be so straightforward. Even teachers with an understanding of the nature of science view this process as linear, instead of expecting it to be dynamic and complex [50]. The teachers in Factor 4 belong to the learning-centred teachers who try to change the ways of thinking of their students and see them as responsible for organizing and transforming personalized knowledge as described by some authors [45, 46]. These teachers search for the reasons which might have led to misconceptions among their students. This suggests that they work with their students individually and are interested in their explanations. Samuelowitz and Bain [45] describe such two-way teacher-student interaction to negotiate meaning. The teacher is still in control of the content but acknowledges the students' interest and motivation. Some authors describe such teachers as the ones who prevent misunderstanding. Their conception of teaching could be expressed as the facilitation of understanding [46].

Conclusion

All the teachers in the study focused primarily on learning knowledge and expressed beliefs about being responsible for its correctness. However, the Q methodology identified 4 groups of teachers which stress different aspects of that vision. Factor 1 teachers emphasize the activity of students in their classroom, Factor 2 teachers feel responsible for the correct outcomes of learning, Factor 3 teachers see the potential in inquiry learning but do not consider it to be applicable for their students, and Factor 4 teachers want to help their students to construct correct knowledge. They all actually concentrate on the content even if they declare the importance of personal construction. The teachers stress that student activity is important, but they do not really work to develop science process skills. The idea of correct knowledge being an outcome of the learning process without pointing to the process of its development suggests that teachers see scientific knowledge as something rather stable. The research findings suggest that systematic trainings focused on the nature of science and the scaffolding process would be beneficial for teachers in all factors.

Acknowledgements

This work was supported by Slovak Research and Development Agency under the contract No APVV-70-0040.

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