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The case of middle and high school chemistry teachers implementing technology: using the concerns-based adoption model to assess change processes

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An ongoing process of reforming chemical education in middle and high schools in our country introduced the technology-enhanced learning environment (TELE) to chemistry classes. Teachers are encouraged to integrate technology into pedagogical practices in meaningful ways to promote 21st century skills; however, this effort is often hindered by teacher concerns and resistance to change. We applied the Concerns-Based Adoption Model (CBAM) to examine whether and how it could be used to identify chemistry teachers' concerns, and to characterize the process of change they experience when integrating TELE. An analysis of two kinds of participants, one of high school chemistry teachers and the other of middle school chemistry teachers, helped us to obtain an in-depth understanding of the way these teachers adopted the innovation. Results revealed that after ten years of implementation, the concerns of high school teachers remained multi-focal, and the *impact* and *personal concerns* increased and were predominant. Examining three case studies of middle school teachers showed that one teacher remained in the early stages of concerns during one year of implementation, while the other two exhibited a process of change, moving forward to advances stages of concerns. Our study can shed light on how CBAM might serve as a diagnostic tool for differentiating between teachers with different qualifications, experiences, and concerns in diverse teaching situations in middle school and high school. Such diagnosis can help stakeholders in the education system to develop specific interventions and activities for different groups of teachers based on specific concerns while implementing TELE.

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Introduction

Educational reforms and teacher change should be inseparable threads in education, but the challenge of achieving both is complex and therefore continues to require attention in all education systems.

Over the last fifteen years, a national reform in chemical education has introduced a fundamental change in the way chemistry is taught and studied in our country. The reform began in high schools about ten years ago and was titled *The New Chemistry Curriculum*† (Barnea *et al.*, 2010). In middle schools, *The National Information and Communication Technologies Program*‡ replaced the traditional instruction style, which was characterized by the memorization of processes and concepts, and a high cognitive load.

The emphasis of the first reform was on chemistry literacy and the role of chemistry in the main life domains such as technology, energy and society (Gilbert, 2006; Shwartz *et al.*, 2006; Dori and Sasson, 2008; Sevian and Bulte, 2015).

Aspects of technology and visualization have also become an integral part of this reform (Kaberman and Dori, 2009; Barnea *et al.*, 2010; Avargil *et al.*, 2012; Blonder *et al.*, 2013). One of the main objectives of the second reform is to implement an innovative pedagogy in the setting of technology-enhanced learning environments (TELE), in which content knowledge, and skills are integrated with relevant ideas related to the changing reality.

The reform emphasizes developing student skills that are necessary to attain their 21st century skills, customizing teaching to student diversity, allowing the teacher to evaluate and give the student feedback in real time, and a teaching–learning–assessing process that focuses on student learning and the development of self-learning (Barak and Hussein-Farraj, 2013; Szteinberg *et al.*, 2014; Dori and Avargil, 2015).

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† http://meyda.education.gov.il/files/Tochniyot_Limudim/Chimia/chelek1.pdf
‡ http://cms.education.gov.il/NR/rdonlyres/79B5A8CF-F812-4A63-89BE-3BEFEB887EC5/142454/12.pdf

The learning environments in high school (HS), and now also in middle school (MS), emphasize meaningful chemistry learning through the use of technology.

The rationale for the development and implementation of TELE for chemistry learning in both high schools and in middle schools, is based on the effort of the Ministry of Education to establish vertical alignment across the basic and advance chemistry learning. For the change to be meaningful, however, it is important to understand how it occurs in terms of teacher concerns (Rogan and Grayson, 2003; Hall, 2013; Rollnick *et al.*, 2015). Successfully adopting any innovation therefore depends on understanding and managing teacher concerns.

In this study, we selected the Concerns-Based Adoption Model (CBAM; Hall *et al.*, 1977) as a theoretical framework for examining the concerns and the change process that chemistry teachers experience while implementing TELE. It is important to note that over the last decade, many studies have examined, tested, and applied the CBAM framework in a wide range of implementation settings; however most studies that have measured concerns and processes of change have been short term and only covered initial implementation and a single period of time (Hall, 2013).

Our study examined the concerns and process of change in: (a) HS chemistry teachers over a period of ten years while implementing TELE, and (b) MS teachers at three points of time over a period of one year. There has also been little research regarding the concerns of chemistry teachers while implementing TELE.

Our fundamental assumption in this research was that change is a process rather than a singular event, and consequently, we focused on the following research question: whether and how the concerns-based adoption model can be used to: (a) identify the concerns of chemistry teachers while implementing TELE; and (b) characterize the process of change in the concerns of chemistry teachers while implementing TELE?

This study suggests how CBAM can differentiate between teachers with various levels of qualification and experience, and in diverse teaching situations, such as MS and HS. This distinction might help educational stakeholders, such as school administrators and change facilitators, develop specific interventions and activities targeted at different groups of teachers while implementing TELE, based on their specific concerns.

Theoretical background

As agents of change, a teacher's concerns about an innovation and the process of change they experience are paramount for the successful implementation of educational reforms in general, and new learning environments in particular. As Fullan (1985) points out, change involves affective elements such as anxiety, uncertainty, perceptions, feelings, and concerns about "why this new way works better" (p. 396). Many reforms haven't been effective due to a lack of understanding of teacher concerns regarding the change, the extent of teacher change required, and how this change occurs (Rogan and Grayson, 2003; Rollnick *et al.*, 2015). We selected the CBAM because it consists of both *Change Theory* (Hall, 1976) and *Concern Theory* (Fuller, 1969). *Change Theory* is based on the idea that teachers can change their instructional practices and perceptions over time (Hall, 2013); *Concern Theory* focuses on the recognition and communication of a teacher regarding their teaching concerns. The model underlines three fundamental assumptions: (1) change is a process rather than a simple and singular event; (2) a change is not significant until the individuals within the organization implement that innovation; and (3) change is experienced differently by individuals, is personal, and involves feelings and perceptions. It is important to note that the term *innovation* represents different types of changes, such as changes to curricula, changes to instructional processes, and educational reforms (Hall, 2013). In our research, innovation refers to the implementation of TELE.

Over the years, the CBAM framework has been demonstrated as a feasible approach, and is a common methodology applied during the process of introducing new innovations, and in particular educational reforms (Anderson, 1997; Chen and Jang, 2014). The model framework identifies seven stages of concern (SoC) which teachers face when adopting an innovation (Anderson, 1997; Hall and Hord, 2011; Khoboli and O'toole, 2012). At the onset, a teacher shows little interest in an innovation (Stage 0 – Awareness).

Certain events then arouse a teacher's interest and they start to seek out more information about the innovation (Stage 1 – Information). After becoming more familiar with the innovation, the teacher desires to know how the innovation will impact their ability to implement it, and what the costs and benefits of implementing the innovation might be from the teacher's perspective (Stage 2 – Personal). At the next stage, the teacher is aware of issues regarding time management, scheduling and balancing different duties (Stage 3 – Management). In Stage 4, Consequences, the teacher starts thinking about ways to upgrade the innovation to increase its impact on students. The teacher seeks collaboration with others to maximize the potential of the technology (Stage 5 – Collaboration). At the highest stage of concern, (Stage 6 – Refocusing), the teacher considers better alternatives that will promote the innovation and would work even better for the teaching and learning process (Chen and Jang, 2014). The seven stages can be divided into three sub-stages: (1) *personal concerns* (Awareness, Information, and Personal), (2) *task concerns* (Management), and (3) *impact concerns* (Consequences, Collaboration, and Refocusing). It is important to note that teachers can experience several stages of concern at the same time and at different intensities, but as a teacher becomes more experienced and skilled with a reform, the intensity of the stages expressed earlier will decrease while the intensity of advanced stages (Consequence, Collaboration, and Refocusing) will increase (Hall *et al.*, 1977; Hall and Hord, 2011; Dori *et al.*, 2005; Chen and Jang, 2014). The early stages of concern characterize teachers who are not experienced with the innovation and are concerned about the impact on themselves. Later stages of concern are focused on the effects, consequences, and better alternatives that the innovation has to offer. In these stages the teacher asks how they can improve and maximize the benefits of the innovation (Hall *et al.*, 1977; Dori *et al.*, 2005).

The importance of teachers' concerns relating to technology implementation is documented in several studies (Casey and Rakes, 2002; Hall, 2013; Chen and Jang, 2014), but the research participants in these studies were not science teachers. Other researchers used CBAM for professional development of science teachers (Loucks-Horsley, 1996) or to evaluate teachers' concerns regarding science literacy (Puteh *et al.*, 2011). However, studies involving concerns that are specific to chemistry teachers who implemented technology in their classes are scarce (Dori *et al.*, 2005). Integrating technology into chemistry teaching and learning is key to being able to explain the abstract nature of chemistry and the constant interplay between the macroscopic and microscopic chemistry understanding levels. Indeed, TELE can provide multiple representations and visualization solutions (Wang and Hannafin, 2005; Dori *et al.*, 2013). However, teachers often feel uncomfortable using TELE due to a variety of aspects, such as inadequate preparation and concerns about or resistance to new approaches (Mouza, 2002; Cox and Marshall, 2007). In view of the importance of TELE in chemical education, understanding chemistry teachers' concerns while using TELE might help predict challenges these teachers face and provide them with suitable assistance, both individually and as a group.

Research about teachers' concerns regarding technology implementation has not focused on a specific science or engineering discipline. Yet, the studies we found have shown that early stages of concern (Awareness, Informational, Personal, and Management) continue to dominate while implementing technology (Newhouse, 2001; Casey and Rakes, 2002; Schoepp, 2004). Both Newhouse (2001) and Casey and Rakes (2002) investigated the concerns of teachers at K-12 levels and found that even though all teachers implemented the technology, the lower stages of concerns were dominant to a great extent. They found that most teachers had high Stage 2, Personal concerns, and that the lowest concern intensity was in Stage 4, Consequence. This means that the teachers were most concerned about how technology would impact them and were not yet demonstrating concern about the impact on students. In all three of the studies conducted by Liu and Huang (2005), Newhouse (2001) and Casey and Rakes (2002), the secondary teachers were not chemistry teachers.

Other researchers have been reflecting on the dynamic and changing nature of teacher concerns and the transition between the different stages (Kim and Baylor, 2008; Hall, 2013). For example, Dori *et al.* (2005) examined the process undergone by chemistry teachers during the implementation of a new case-based computerized laboratory, and found that at the end of the program a much lower percentage of the teachers were at the introductory Awareness stage, and more had concerns at the Management and Consequences stages. Liu and Huang (2005) examined teacher concerns related to technology integration and identified three groups of teachers based on their use of technology: beginning, intermediate and advanced. The results reflected the SoC shift from self to *task* and *impact concerns*.

It is also important to recognize that having positive views about technology, and a belief in the potential of technology to improve teaching and learning, is not enough for the significant implementation of technological innovations (Ertmer and Ottenbreit-Leftwich, 2010). There are more complex constructs, such as the process of change that teachers experience, and their concerns during the change, that need to be addressed before an innovation is successfully adopted in their practices (Hall and Hord, 2011). We thus applied the Concerns-Based Adoption Model to identify the concerns and characterize the process of change that chemistry teachers experience when integrating TELE. To probe this process, it is essential to examine innovation adoption over a long period of time, and at a few specific points of time, as we did in this research. This characterization is important because it can help develop specific interventions and activities for different groups of chemistry teachers based on specific concerns while implementing TELE.

Research setting and TELE environment

In this study we focus on two technology based modules that were developed as a result of the reform. The chemistry learning module *Taste of Chemistry* was developed ten years ago in order to align teaching, learning and assessment with the reform in high schools. The module implemented components of the technology used in case-based and inquiry-based computerized laboratories (CCL) along with web-based assignments and computerized molecular modeling (CMM). The TELE components in the CCL & CMM had a major impact on students when they conducted their experiments and improved both their question posing abilities and their graphing and modeling skills (Dori and Sasson, 2008; Dori and Kaberman, 2012). The learning module *Taste of Chemistry* integrates chemical concepts and processes of food chemistry, presenting chemistry as a relevant topic in the everyday lives of students. The teachers who participated in the research represent a small sample of teachers who taught this module for about two months.

After the major reform was implemented in high schools, a reform in middle schools followed, with the aim of vertically aligning the teaching methods and approach with those implemented in high schools. The TELE that MS teachers implemented was based on a web-based management system and included the *Wired for Chemistry* module. Chemistry teachers taught the module *Wired for Chemistry* for about a month and a half. This module emphasized aspects similar to those emphasized in the *Taste of Chemistry* module: both encouraged collaborative learning, context-based chemistry, multiple representations, moving between representations such as graphs, tables and molecular structures, and meaningful chemistry understanding. The module contained digital instruction materials focused on various chemistry topics, computerized activities and teachers' tools for managing student learning. The activities are based on simulations, short films, computerized molecular models and interactive online learning. The main topics and

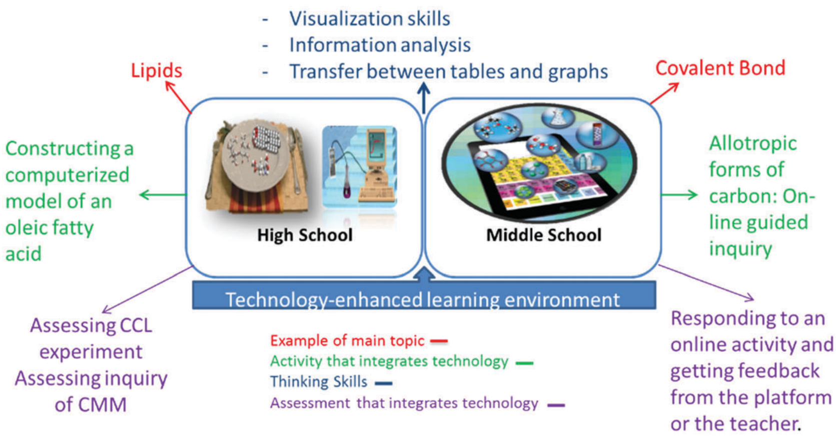

Fig. 1 Examples of commonalities between the learning environments of middle school and high school.

Table 1 Examples of main topics and chemical concepts in the *Wired for Chemistry* and *Taste of Chemistry* modules

Topic	Chemical concepts and processes	Main activities
Wired for Chemistry		
The uniqueness of the carbon atom	Various forms of arrangement of atoms and electrons and their connection to material properties and usage are explored. There is a large number of carbon compounds derived from carbon chains in the form of rings, polymers, *etc.*	• Fill in tables online: characteristics of diamond and graphite. • 3D simulations, and classroom discussions: molecular representations of the structures of diamond and graphite. • Responding to an online activity and participating in a discussion forum.
Taste of Chemistry		
Lipids	Structure and types of fatty acids and converting chemical formula into two types of structural models. Investigating the double bond in fatty acids using plastic and computerized molecular models. Understanding the connection between molecular structure of fatty acids and the substance properties. Information analysis and transfer between tables and graphs	• Constructing a computerized model of an oleic fatty acid. • Studying the spatial structure of a molecule and its rotation around a single and double carbon–carbon (C–C) bond. • Conducting an acid–base titration of extra-virgin olive oil using pH sensors and connecting them to the data collection apparatus.

characteristics of the modules are presented in Fig. 1, which shows examples of commonalities between the learning environments such as the activities that integrate technology, thinking skills, and assessment.

In Table 1 we show an overview of the main topics and chemical concepts in the two modules (for more information about the modules see Appendices 1 and 2).

Teachers who taught using TELE either in HS or MS participated in summer long professional development (PD) aimed at either MS teachers or HS teachers. The PD of HS and MS teachers lasted about 30 hours during the summer, as well as additional individual meetings. Fig. 2a and b show the timeline of the research for high and middle school teachers respectively. In Fig. 2a, the 10 year time gap between the first and last two stages of the study is indicated by the zigzag shape. During these 10 years, the intensity of implementing TELE was gradually reduced due to technological modifications and a lower level of both technological and pedagogical support the teachers received.

During the teaching period, we maintained close contact with the teachers, held personal meetings with some of them, and supported others through emails, clarification calls, and a website containing a complete teacher guide, additional assignments, and test options created by both the developers and the teachers. These aspects of supporting teachers are aligned with the literature recommendations for quality PD, which includes a long duration, personal contacts, follow-ups, access to new technologies, meaningful and relevant activities for the individual contexts of teachers, community building, and addressing student assessment (summarized by Lawless and Pellegrino, 2007). This support was not part of the research tools or methodology for capturing teacher concerns and processes of change in their concerns; however, it is important to note it since it was part of the support system provided for teachers when implementing the new set of instructional materials.

Research methodology

Our research question was whether and how the concerns-based adoption model can be used to identify the concerns of chemistry teachers and characterize the process of change in the concerns of chemistry teachers while implementing TELE. To answer this question, we employed a qualitative approach and

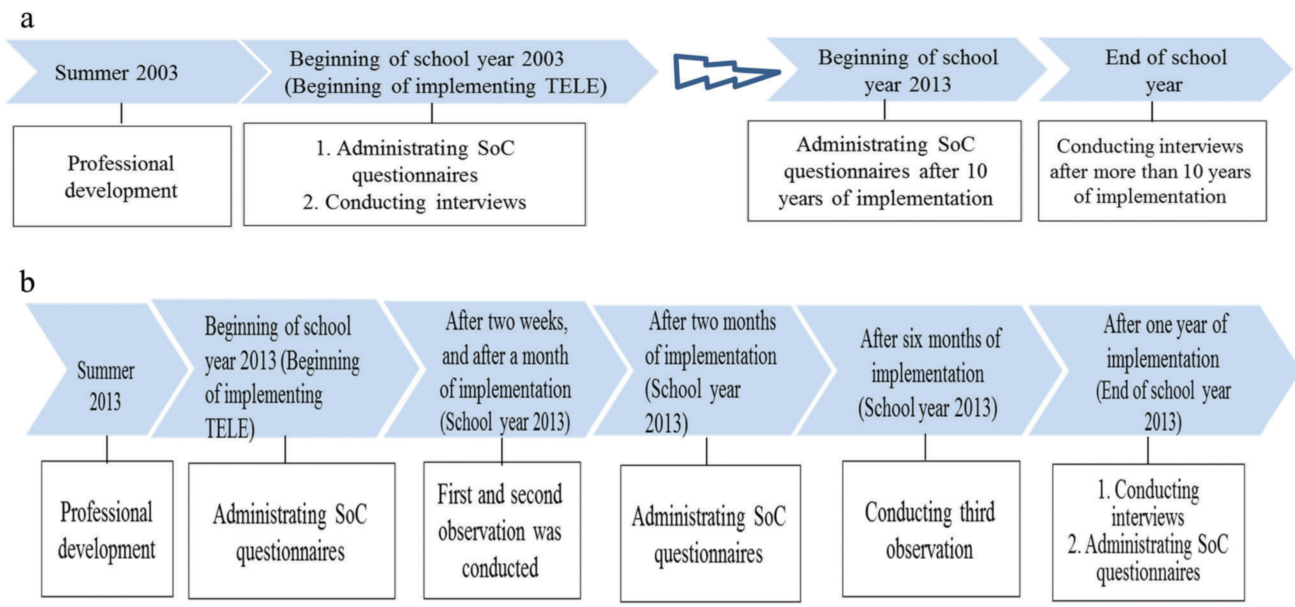

Fig. 2 (a) Research timeline for HS teachers. (b) Research timeline for MS teachers.

descriptive analysis of the data (Erickson, 2012) together with a closed-ended questionnaire. We combined both open-ended and closed-ended data in the investigated case (Creswell, 2014), including semi-structured interviews, observations and the Stages of Concern Questionnaire (SoCQ) (Hall *et al.*, 1977; Hall, 2013; Chen and Jang, 2014). These research tools provided us with the best comprehensive understanding of the research problem. The triangulation allowed us to increase the validity of the findings, to reduce the subjectivity of our interpretations, and enhance the trustworthiness of the conclusions (Golafshani, 2003; Jonsen and Jehn, 2009).

Research participants

Participants were viewed as two cases. For the first case, we selected eight HS chemistry teachers who had participated in a study about ten years ago when the reform in HS chemical education was in its early stages, and who still taught chemistry. HS teachers taught 10th–12th grade students. For the second case, we selected six science teachers who taught according to the reform in middle schools. MS teachers taught 7th–9th grade students. The study sample was drawn from the accessible population; participants were volunteers who gave permission to be interviewed and to be observed during three class sessions. The participants are not necessarily representative of all chemistry teachers and this may be seen as a limitation of the study. They are likely to be representatives of "high involvement" chemistry teachers (Lasky, 2005) who are active in many areas of school life. Even though they are not necessarily representative of all chemistry teachers, the concerns of this set of teachers, who formed a community voluntarily to enact TELE, and the investigation of the change in their concerns, might help educators, as well as other teachers, to be more prepared for implementing TELE, and also show that the actual comprehension and reform may take some time to accomplish.

It is important to note that the HS teachers were homogenous in terms of their demographic characteristics. These included (a) their teaching experience at the time of the first study – most HS teachers had between 6–15 years of experience, (b) academic background – most had a PhD, and (c) most of them had BSc in chemistry and advanced degree(s) in chemical education. The MS teachers were more heterogeneous in terms of their teaching experience (some were novice teachers and some were experienced) and half had an educational background in biology, a BSc and a teaching certificate. The HS teachers taught students who chose to major in chemistry, and the MS teachers had previously taught general science to all students, and chemistry was integrated into their existing curriculum. The new reform contains an explicit reference to chemistry, and specific teaching hours and content were defined in the syllabus. Students were therefore exposed to chemistry in a more direct, continuous, and extensive manner (Ministry of Education, Pedagogical Division, The Science and Technology Curriculum, 2014).

We can see in Table 2 that despite the fact that participants were drawn from the accessible population, the demographics of these teachers represent varied levels of teaching experience, academic background, and educational discipline.

The group of HS teachers had participated in a study conducted some ten years ago when the reform in HS chemical education was in its early stages (Dori *et al.*, 2005). In this research, they were asked to fill in questionnaires and respond to interview questions in order to examine their concerns and processes of change after ten years of implementation.

The study was approved by the ethical committee of our institution which serves as the review board (IRB) for studies conducted in the institution. All teachers in the study gave their consent to be part of the research and filled in the questionnaires. Teachers who were additionally interviewed and observed agreed

Table 2 Demographics of the middle school and high school teachers who implemented TELE

		School	
	Demographics	HS chemistry teachers	MS science teachers
Gender	Female	7	5
	Male	1	1
Teaching experience (years)	0–5	1	4
	6–15	5	0
	16–25	1	0
	More than 25	1	2
Academic background	BSc and teaching certificate	8	1
	MSc	3	3
	PhD	5	2
Educational background	Chemistry	7	3
	Biology	1	3

that this data could be included in the research. To protect confidentiality and ensure that all data remained confidential, the participants were given pseudonyms, and school names and any other identifying details were removed from the data.

Research tools

The research tools included interviews, questionnaires and the case studies of three MS teachers who, in addition to being interviewed and answering the questionnaire, were also observed in their classrooms.

Interviews

Semi-structured interviews were conducted with all 14 teachers; MS teachers were interviewed after a year of implementing TELE, and HS teachers were interviewed at the beginning of the implementation and after ten years of implementation. The purpose of the interviews was to identify and examine teacher concerns and processes of change while implementing TELE-based chemistry. We designed a guided interview (Patton, 1990) which included a pre-prepared set of questions for documenting teacher concerns (see Appendix 3, Table 7). All the questions were open-ended, and teachers could express themselves freely, based on their choice. The questions were divided into three main elements: the use of technology, facing difficulties and challenges while implementing TELE-based chemistry, and technology advantages.

The analysis procedure began with two researchers extracting all statements from the interviews that appeared to be related to concerns and challenges while teaching in a TELE. These statements were sorted by the three sub-stages described in the theoretical background: (1) *personal concerns*, (2) *task concerns*, and (3) *impact concerns*. Three researchers reviewed the evidence, and working by consensus, divided these statements into the three sub-stages of concern. This categorization allowed us to examine the concerns of both MS and HS teachers while implementing a new chemistry curriculum following the educational reforms for high schools and then for middle schools.

Questionnaires

The questionnaire was based on the Stages of Concern Questionnaire (SoCQ) developed by Hall and colleagues (1977) and based on CBAM. The SoCQ was given to: (a) six MS teachers before, during and a year after implementing the TELE module; and (b) eight HS teachers at the beginning, and after 10 years of implementation of the chemical education reform. The questionnaire includes 35 items and uses an eight-point Likert scale (0 = strongly disagree, 7 = strongly agree) to gauge a teacher's stages of concerns. High numbers indicate high concern, low numbers indicate low concern, and 0 is indicative of very low concern or items not considered relevant by the respondent. The 35 items are classified into seven stages of concern and each stage is represented by five statements. It is important to note that the seven stages are not necessarily hierarchical: participants can identify with several stages simultaneously. The seven stages of concern, and an example of a statement for each of the stages in the questionnaire (Hall, 1976; Hall *et al.*, 1977), are presented in Table 3.

The analysis process contained two main phases. The first phase was to calculate the "raw score" for each stage of concern. Once the seven raw scores were obtained, the second phase was to convert these to percentile scores for interpretation (see Hall, 1976, Figure III.4, p. 36). The data can be displayed in several ways: (1) graphical representation of the percentile scores, (2) tables, and (3) statistical analysis. To accommodate the qualitative

Table 3 Stages of concern and relevant statements

Stage	Description	Example of a statement
Stage 0: awareness	Teacher shows little interest in the innovation.	*I am not concerned about this innovation*
Stage 1: informational	Teacher starts to seek out more information about the innovation.	*I want to know more about this innovation.*
Stage 2: personal	Teacher wants to know how the innovation will impact their ability to implement it and the costs and benefits for them.	*How is this TELE going to affect me?*
Stage 3: management	Teacher is concerned regarding organizing, scheduling and time demands during the implementation process.	*I seem to be spending all of my time getting materials ready.*
Stage 4: consequence	Teacher focuses on the innovation's impact on students.	*How is using TELE going to affect students?*
Stage 5: collaboration	Teacher cooperates with other teachers in implementing the innovation to maximize the potential of it.	*I want to see more cooperation among teachers as we work with this innovation.*
Stage 6: refocusing	Teacher considers the benefits of the innovation and thinks of additional alternatives that might work even better.	*I have some ideas about something that would work even better than TELE.*

nature of our study, we chose to display the data *via* tables and graphical representation. Interpretation of the percentile scores can also be done at several different levels. The simplest is to relate and interpret the highest score. Interpretation of the highest score is based directly on the definitions of the stages of concern about implementing the innovation. A broader interpretation is to identify and examine both the highest stage score and the second highest stage score. In this study, we identified the concerns of HS and MD teachers by determining the first and second highest stages of concern using a percentile rank table (see Hall, 1976, Figure III.4, p. 36) and calculating the frequency of each stage. Lastly, the most comprehensive interpretation is to develop a complete profile for an individual or a group. It is important to note that the interpretation of concern profiles is based on the shape of the graphic representation rather than the concrete percentile number and where the intensity of the concerns falls in the graph. We examined the concerns and processes of change while implementing TELE for HS chemistry teachers over a period of ten years, and MS teachers at three time points over a period of one year. We depict the process of change graphically for both teacher groups. In what follows, we present case studies of three individual MS teachers and profile graphs of HS and MS teacher groups over time.

Case studies of three middle school teachers

A multiple case study design (Stake, 2013) was chosen to promote the in-depth understanding of MS teachers: (a) concerns while implementing TELE; and (b) process of change in their concerns while implementing TELE at different points of time. In multiple case studies each case is treated individually but all cases have some similarities. Of the six MS teachers, only three teachers, Yona, Zohar, and Sharon,§ served as case studies and were selected for observations while teaching the subject "Carbon and its Compounds" using the TELE. As noted, MS teachers were heterogeneous in terms of their teaching experience and educational background. When we analyzed their SoCQ as a group, we found that it was difficult to understand their concerns and to obtain an in-depth understanding regarding the process of change they experienced as a group, and therefore we chose to focus on three individual teachers who were selected because: (1) we wanted to give an overview of MS teachers with different teaching experience, which meant we chose Zohar as a new teacher, and Yona and Sharon who had over 25 years of experience; (2) they have different academic and educational backgrounds, wherein Zohar had a BSc and a teaching certificate in chemistry, Yona had an MSc and a biology background, and Sharon had a PhD in chemistry along with teaching certificate.

We conducted three observations in each teacher's classroom (after two weeks, a month, and six months – during the final stages of implementation). All the lessons dealing with the subject of "carbon and its compounds" lasted 45 minute. We conducted a thick description of the lessons and later analyzed it within the three main sub-stages of concerns: *personal, task, and impact concerns*. Our analysis of the case studies in general and the observations conducted in particular included the identification of three aspects of teacher concerns: *personal concerns* (Awareness, Informational, and Personal), *task concerns* (Management), and *impact concerns* (Consequences, Collaboration, and Refocusing). For example, in one of the observations the teacher was struggling with the technological environment and couldn't open the specific presentation she was looking for. She asked the researcher to help and guide her during the lesson. We can see that this teacher has *personal concerns* about her ability to manage the TELE platform. In another observation, the teacher used one of the *Wired for Chemistry* components, and in order to reinforce student understanding, he showed them a short video clip on the same topic and asked the students some questions. This shows that this teacher has *impact concerns* and thinks about how he can modify and improve the technology so that the learning and teaching processes are meaningful. Finally, in order to build a comprehensive case for the observation data of each teacher, a teacher's unique SoCQ graphs and interviews were compared and combined.

§ Pseudonyms.

Results

We structured the results section according to our two research questions. For identifying middle and HS teachers' concerns at the beginning of implementing TELE we analyzed their individual SoC profile and determined the first and second highest stages of concern for each teacher using the percentile rank table (see Hall, 1976, Figure III.4, p. 36). For characterizing the process of change in teacher concerns, we graphically present the SoC profile; for HS teachers we present the SoC profiles for all teachers as a group at two points of time – at the beginning and after 10 years of implementation. For MS teachers we present individual profiles of three teachers at the beginning of implementation, during and after a year of implementing TELE. Our reasons for this are: (1) we wanted to emphasize that the characterization of concerns and change using CBAM can be done individually as well as in groups of teachers, (2) HS teachers present a homogenous group in terms of their demographic characteristics, such as their teaching experience, academic and educational background, compared to MS teachers. Interviews and observation analysis are presented in order to characterize the process of change. It is important to note that during the interviews, positive aspects regarding the implementation of technology were addressed by HS teachers as well as by MS teachers. All teachers felt that the technology helped them to support student visualization of molecular structures and to demonstrate chemical processes at the microscopic level. The belief of teachers in the power and potential of technology, despite their concerns, is a productive stage towards enabling them to deal with these concerns and implement TELE in a successful way in the future.

Concerns of middle and high school chemistry teachers at the beginning of the implementation

Interpretation of the highest score of concerns at the beginning of the TELE implementation was based directly on the definitions of the stages of concern about implementing the innovation. According to Hall *et al.* (1977) all stages other than Stage 0 can be directly interpreted based upon this highest stage. Stage 0 has two different meanings depending on whether the respondent is a non-user or a user of the innovation. For non-users of the innovation, a high peak score at stage 0 reflects awareness of the innovation, while for users, a high peak at stage 0 indicated lack of concern about the innovation. Since our participants were users of TELE (the innovation) and we wanted to investigate their concerns, we decided not to include this stage when calculating the frequency of the highest stage of concern. Four out of eight HS teachers scored Stage 5 (Collaboration) as their highest concern; three teachers scored Stage 6 (Refocusing) as their highest concern, and one teacher scored Stage 3 (Management) as their highest concern. Examining the second highest concern of these teachers revealed that three teachers scored Stage 2 (Personal) as their second highest concern, and five teachers scored Stage 1 (Information) as their second highest concern. We can see that HS teachers' concerns were focused on two main aspects: on the one hand more than 80% expressed high *impact concerns*, as they tended to cooperate with colleagues and felt confident enough to come up with their own ideas for modifications and improvements of the TELE. On the other hand, all teachers expressed *personal concerns*, as they felt they need more information and still had concerns regarding the effect of the TELE on them. High *impact concerns* can be explained by the fact that even though these teachers were in the beginning of implementing TELE, they were mostly very experienced chemistry teachers who prepared students for the matriculation exam and the impact of TELE on their students was a high priority for them. They wanted to maximize the potential of the technology and thought about alternatives that could promote the use of TELE and improve the process of teaching and learning with technology. They were still unfamiliar with the TELE and therefore demonstrated the introductory stages of concern, such as Personal and Information concerns.

Three out of six MS teachers scored Stage 1 (Information) as their highest concern; two teachers scored Stage 2 (Personal) as their highest concern, and one teacher scored Stage 5 (Collaboration) as their highest concern. Three teachers scored Stage 2 (Personal) as their second highest concern, two teachers scored Stage 1 (Information), and one teacher scored Stage 3 (Management) as their second highest concern. The first and second concerns of all MS teachers involved the introductory stages of concern. This suggests that MS teachers desire to know how the innovation will impact their ability to implement it, and what the costs and benefits of implementing the innovation might be from the teacher perspective. The early stages of concern characterize teachers who are inexperienced with the innovation and are concerned about the impact on themselves.

Process of change for middle and high school chemistry teachers

Using the SoCQ graphs, we compared the change in HS teachers' concerns during the TELE-based chemistry implementation and

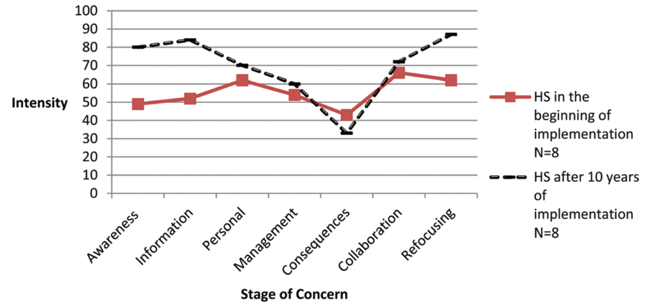

Fig. 3 High school (HS) teacher's concerns regarding TELE implementation.

considered each concern that scored 50 or higher as a high level concern in each category.

The dynamic nature of high school chemistry teachers' concerns

Fig. 3 shows a comparison of HS teachers' concerns at the beginning and after 10 years of implementation.

It is important to note that in CBAM framework the SoCQ graphs plotted over the different stages of concern should form a graph in which the dots are connected by a segmented line. The assumption is that the transition between the different stages of concern over time is continuous. Data is therefore presented in segmented line graphs (rather than bar graphs) for the best assessment of the complete concern profile (standard deviations are reported in Appendix 4, Tables 8 and 9).

Fig. 3 shows that at the beginning of implementation the main concerns of HS teachers when implementing TELE were related to Personal, Management, Collaboration, and Refocusing issues. After ten years of implementation, teacher Awareness, Informational, Personal, Management, Collaboration, and Refocusing concerns increased. We found that there was a change in the profile of teachers' concerns over time – there was a wider gap (difference) between the intensity of concerns of the HS teachers after 10 years than at the beginning of implementation. In the segmented line, which presents the HS group at the beginning of implementation, the difference between the highest concern, Collaboration, and the lowest one, Consequences, is about 25 points. In the segmented line, which represents the HS group after 10 years, the gap from the highest concern, Refocusing, and the lowest one, Consequences, was about 55 points. The concerns of the introductory stages, which consist of Awareness and Information, increased greatly over time. Triangulating the data from the SoCQ with the interviews, we can see a similar picture of concerns and change. Table 4 present teacher concerns at the beginning of implementing TELE and after 10 years of implementation.

In analyzing the interviews with HS teachers at the beginning and after 10 years of implementation we can see a change in the type of concerns they expressed. At the beginning of implementation, HS teachers were most concerned with *personal* and *impact concerns*. After ten years of implementation, all teachers mentioned time constraints – management concerns as a challenge in implementing the TELE; as Batya noted in Table 4, time management aspect was a main concern as she felt she couldn't prepare the students to

Table 4 High school teachers' concerns at the beginning and after 10 years of implementation

Statements at the beginning of implementation	Statements after 10 years of implementation
Personal concerns (Awareness, Information, and Personal)	
Ronit: [...] *I did not know how to approach [the Taste of Chemistry] module from a pedagogical aspect. I had many difficulties; I wasn't sure how to teach the different skills, and especially how to guide my students to read tables and graphs using technology*. Gali: ... *Now, I need to assess various skills such as data analysis from tables and graphs, and I really don't know how to compose and incorporate such questions using technology and how to assess these type of thinking skills*	Amit: *Integrating technology requires a change in teaching methods so that the pedagogy and technology help in constructing the knowledge of the student*. Ronit: *Teachers need to undergo professional development courses in which they learn the principals of integrating technology, experience developing online actives and practice different technological applications*. Irena: *The technology often does not serve my pedagogy and is a "gimmick" while teaching*. Hila: *I need to adapt my pedagogy to the technological tools so it will serve the content I want to teach*
Task related concerns (Management)	
Yasmin: *Most of the time either the internet or the computer is not working. There are many technical problems, which affects my teaching*.	Batya: *The most significant challenge for me is time constraints. The time that we have to prepare the students for the matriculation exam given the hours we teach and the extent of material, doesn't leave much flexibility to integrate technology in a meaningful way* Nimrod: *I don't integrate technology a lot because at the end of the day we have the matriculation exam that the students need to be prepared for. Sometimes, the difficulty is also the technical support in school*. Hila: *The main problem that prevents teachers integrating technology is time constraints*.
Impact concerns (Consequences, Collaboration, and Refocusing)	
Hila: *It was important for me that students will know how to transfer between various computerized and non-computerized molecular modeling*	No statements were coded in this category

Table 5 Frequency of statements HS teachers made, sorted by the three sub-stages of concerns

Category	Frequency of statements HS teachers made at the beginning of implementing TELE	Frequency of statements HS teachers made after 10 years of implementation
Personal concerns	4	8
Task related concerns	2	10
Impact concerns	4	0

the matriculation exam as required and invested the time in implementing TELE. Personal aspects of professional development and guidance were mentioned by more than half the teachers. For example, Ronit explained that the exposure of teachers to professional development programs is important for gaining experience in a variety of technological tools.

In addition to the categorizations process of the interviews, and in order to validate the process of change reflected in the SoC profiles, we counted the number of statements HS teachers made during their interviews, according to the *personal, task*, and *impact concerns*. Table 5 presents the frequency of the statements that HS teachers made at the beginning and after 10 years of implementation.

Analyzing the *personal concerns* during the implementation of the TELE showed that all the statements were related to the current practice and teaching methods of the teacher, however after ten years, the *personal concerns* were different – the teachers talked about their pedagogy in general, and adjusting this pedagogy to the relevant technology. We can also see that more statements addressed *personal* and *task concerns*, which was also reflected in the SoC profile after ten years of implementation. This means that the personal aspect, which deals with teacher perspectives regarding the costs and benefits of implementing TELE, together with time constraints, is the main concern of HS teachers after ten years of implementation.

Characterizing middle school teachers' process of change by individual profiles

Three teachers, Yona, Zohar and Sharon, were MS teachers who served as case studies. They taught chemistry in their classes using the *Wired for Chemistry* module. Our analysis of the case studies sought to examine and identify (a) the different concerns and challenges that teachers not only reported, but also encountered, when implementing TELE-based chemistry in real time; and (b) to characterize in depth the process of change in the concerns each teacher encountered over one year of implementation.

In addition to the aim of validating and ensuring the credibility of the observations during the implementation in the case study classes, we compared our data to each teacher's individual SoCQ graph data at three points of time, and to their interviews after a year of implementation.

Early stages of concern profile. We observed Yona while implementing the *Wired for Chemistry* module. The lesson described below, from the final stages of the implementation, dealt with the carbon atom and its uniqueness. It was a 45 minute lesson, which started with a presentation taken from the digital platform. The teacher reviewed the assignments with the students, showed short videos and various examples. A description of the observation follows:

The lesson started by Yona asking the researcher: *Do you prefer that I use the [digital] platform right now or later?* The researcher answered that Yona can feel free to organize the lesson as best she sees fit. Then, Yona opened the digital platform and started to read the instructional material: *The four valence electrons of the* *carbon atom enable the sharing of valence electrons with other atoms... [Stops and turns to the students]: Who remembers what valence electrons are?* The students cooperated and one of them responded: *These are the electrons in the outer shell of the atom.* Yona answered: *Correct. What is the importance of these electrons?* Another student replied: *All atoms have them*. Yet another student participated and said: *Oh, we know whether the element is a metal or non-metal by the number of valence electrons*. Yona did not relate to the students' answers and continued reading from the screen: *Valence electrons allow the atoms to create single bonds, double bonds or triple bonds with other atoms*. [Stops and turns to the students]: *Who can draw a compound on the board in which there is a double bond between two carbon atoms?* When no one volunteered, Yona turned to the board and drew an incorrect Luis drawing of the double bond between two carbon atoms. Following this drawing, they talked about the uniqueness of the carbon atom. Yona tried to show the students a short video clip from the platform, but encountered difficulties while trying to start the clip. She turned to the researcher and asked for help. After watching the video, Yona continued reading from the digital platform without discussing it further with her students. In the remaining time of the lesson, she read from the screen and sometimes clicked on the interactive links to explain important concepts and addressed them only by reading the text. On one occasion she clicked on the interactive link and did not even read it; rather she closed it immediately. By the end of the lesson, she gave the students homework – a worksheet in the digital platform dealing with covalent bonds and asked them to print their answers and to submit a hard copy rather than using the evaluation option of the platform.

The main interpretation of Yona's observations was that integrating the platform during the lessons appeared forced and she tried to avoid using it. Moreover, we did not observe a harmonious integration between the digital-technological instruction materials, and the teacher's classroom instruction. By simply reading the digital content, without expanding or enhancing the scope of instruction, the use of the digital content was ineffective, as it did not prompt meaningful discussion. The TELE platform enables one to click on an important concept, which thus promotes discussion on topics related to the relevant material. For example, when Yona asked a student to click on the relevant concept, she read the content and continued the lesson without referencing the instruction. At many points when the digital content enabled the teacher to expand an explanation on important concepts, Yona simply clicked on the link, and closed the window immediately. Additionally, she gave the students homework from the digital platform but specifically asked them to "print and hand it out" when they could simply send it to her through the platform and she would have evaluated them using the technological environment. Another important aspect to be addressed is Yona's content knowledge, which was lacking in that observation. There were several inaccuracies, such as the Luis drawing of the double bond between carbon atoms. In her interview Yona expressed her reservations about the integration of technology, for example she said: "*The computers in schools are generally inadequate, three-quarters of*

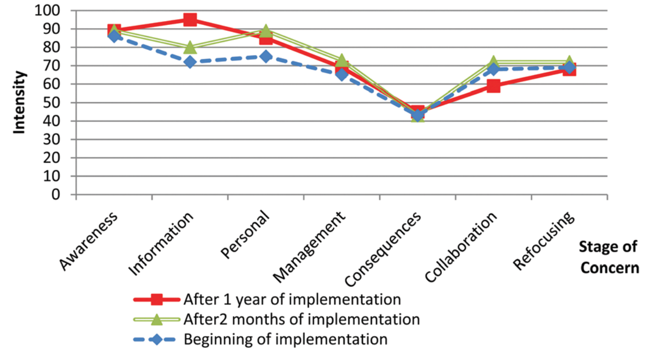

Fig. 4 Stages of concern questionnaire of Yona while integrating TELE.

a lesson is wasted on simply trying to turn on the machine and make them useful. Since so much time is wasted, I prefer not to use the computers". We can see Yona has time management concerns. Time management issues were also observed when Yona asked the researcher to guide her when to use the digital platform. She also expressed *personal concerns*, saying: "*there is great difficulty in curbing the inability of students to focus*". Yona's weak content and technological knowledge could affect her *Personal concerns*. Asking for help during the lesson showed that she felt uncomfortable in operating the TELE.

In summary, it remained difficult for Yona to integrate her traditional teaching style, which included meaningful discussions, with the use of technology. It is thus important for teachers to understand how to integrate technology, discussion, and traditional teaching styles together.

When we analyzed Yona's SoCQ graph, as seen in Fig. 4, we saw that her highest stage of concern was Information at the beginning of implementation, Personal, after two months of implementation, and Information after a year of implementation. Her least concern at these three points of time was Consequences. It is evident that the early stages of concern continue to dominate while implementing technology. This means that Yona is most concerned about how the TELE would impact her and not yet demonstrating any concern for the impact upon her students. A teacher with this profile is interested in more information about the innovation, however, they are not yet sure whether or not the innovation suits them with regard to its effect on their teaching. These results support our observations in Yona's case study. In the classroom, there was no significant use of the TELE. This can be explained by our finding regarding the stages of Yona's concerns. Yona's concerns related to her personal status as a teacher, and time-management concerns led to a superficial implementation of the web-based platform. The *Personal concerns* might relate to her technological and content knowledge difficulties as we saw in the observation.

Multifocal concerns – intermediate phase toward a process of change. Sharon, although volunteering to implement TELE, was reluctant to embrace the change according to our analysis. At first, we offered her close support and assistance while implementing the system, however; after continuous refusal and delays, we proposed, and Sharon agreed, that a representative from our team, who is familiar with the platform, would co-teach

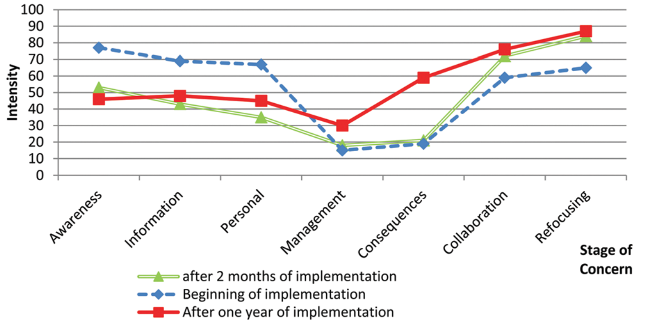

Fig. 5 Stages of concern questionnaire of Sharon while implementing TELE.

the "carbon and its compounds" module with her. Follow-up reports from web-based management system administrators indicated that Sharon did use the evaluation and assessment tools found within the Learning Management System (LMS) component of the platform. Using the LMS, Sharon effectively provided feedback to students regarding their tasks and assessments in a meaningful way. It was apparent that Sharon was reluctant to implement the pedagogical and content components of the *Wired for Chemistry* module during class. Instead she preferred to use the system as a tool for assessment. In her interview she also noted that student assessment is important and said: "*There is a need to expand the practice and the variety of questions in all topics. Additionally, to add more online activities and additional worksheets so the students can practice the material.*"

In analyzing Sharon's SoCQ (Fig. 5) we saw that her highest concern at the beginning of implementation was Information and after two months and a year of implementation it shifted to the Refocusing stage. Sharon's primary point of concern was Stage 6 – Refocusing. Sharon's high intensity score at Stage 6 after two months, and after a year indicates that she was: (a) interested in exploring options for future, effective implementation of the system, and (b) was actively undergoing a process of change. Sharon's considerations for future use of the system, after using the LMS portion of the system at the beginning of the implementation, together with her SoC profile, suggests that Sharon is now concerned with the way she currently uses the system, and how she might use it in the future. We can see that the stage that Sharon is least concerned about is Management. Since she is a very experienced teacher, she knows how to manage and prepare her lessons while using TELE.

Moving from early to advanced stages of concern. We also carried out an observation of the *Wired for Chemistry* module implementation in Zohar's class. The lesson described here, from the final stages of the implementation, dealt with materials and their impact on people, the public and the environment. More specifically, it focused on recycling and the different stages in the life cycle of a product. The lesson lasted an hour and a half and started with a video clip within the platform. A description of the observation follows. The class started with Zohar explaining to the students how he can evaluate their work using the digital platform and how they can send their responses to him. He turned the platform on and showed them the teacher's screen and the different elements the teacher can see. He said: *I want to share with you what I see as a teacher and guide you how to send me your materials and homework*. The lesson continued with a video clip, and when it ended, Zohar asked the students to explain: *What is the life cycle of a glass bottle? What is special about glass?* One student answered: *It is a material that cannot decompose*. Zohar replied: *That's right. Could you give me an example of another material that is decomposable?* While the students were thinking about their answer, Zohar approached the board and began sketching the life cycle of a glass bottle. Addressing the students, he asked them to summarize the lesson. Then, Zohar explained: *The subject of recycling is very important nowadays and it involves a lot of aspects of our life. One aspect is waste recycling. I ask you to read the article in the platform and answer the questions that follow it. Then, each one of you will find another aspect of recycling using the web, and present the aspect he/she chose to the class*. Next, students worked together in groups while Zohar helped them to search a suitable on-line article and guided them how to present this article to their peers. In Zohar's lessons, we saw that the teacher used a variety of technological tools, such as the web-based management platform, video clips and articles. He showed the students how they should send him their assignments using the technological environment and emphasized that he would evaluate their work using it. It was important for him to guide them by showing the teacher's screen. He used the TELE harmoniously and connected the pedagogy with the content. The combination of different teaching methods and incorporating the TELE enabled Zohar to expose the students to different aspects of recycling. The teacher did not encounter technical difficulties in operating the digital instruction materials and felt comfortable in navigating through the system as observed at the beginning of the lesson. In Zohar's interview he said: "*I liked the content, what the platform has to offer. I did not feel any difficulty in implementing the system and integrating it during instruction. You can say it is "user friendly" – at least in the ways I chose to use it. The connection to everyday life is very important and is reflected in the system*". We can see that Zohar expressed *impact concerns* (see Fig. 6).

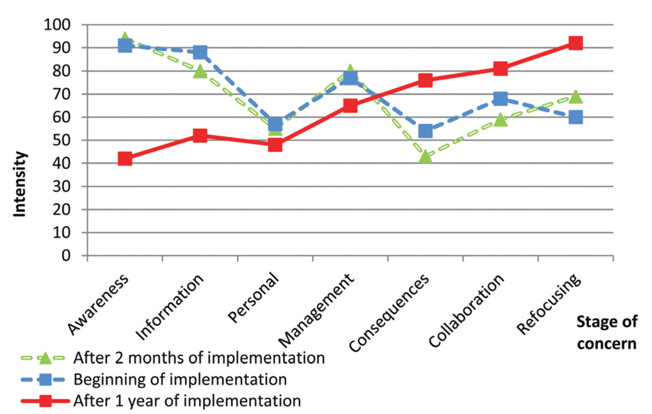

Fig. 6 Stages of concern questionnaire of Zohar while implementing TELE.

He continued, and said regarding the impact of TELE on his students: *It is important to connect technologically-oriented students with the most relevant and fascinating topics. This demonstrates to the students that the topics being learned are not from old, dusty books, which may appear irrelevant*.

When analyzing Zohar's SoC profile we saw an interesting shift from the introductory to the advanced stages of concern. At the beginning of implementation, his first highest stage of concern was in the Management and Information stages, and after a year of implementation it was in the Refocusing, Collaboration and Consequence stages. The profile implies that this teacher's concerns are changing to the advanced stages of concern while implementing TELE, and becoming a more experienced user. At the beginning of implementation, this teacher had a high score in the Management stage, indicating that his concerns related to organizing, scheduling, and the time demands required during the implementation of the TELE. It is not surprising that one of this teacher's most salient concerns related to time management, as Zohar is a teacher with little teaching experience. His high score in the Refocusing stage, after a year of implementation, indicated that he reflects on his teaching, and has ideas about how to improve the use of the TELE in his classes.

These results support our case study observation of Zohar. While using the platform with the *Wired for Chemistry* module, Zohar did not encounter any technical problems, and simultaneously combined the use of the system with several teaching methods. According to his SoC profile and case study, Zohar was still trying to navigate implementation of the system; Zohar's thinking pertained to the advancement and promotion of teaching and learning processes while using the system in a time efficient manner.

Lessons learned from the case studies. The case studies have demonstrated that individuals' paths of change processes can vary due to the heterogeneity of the MS teachers' group. One of the factors that influence a teacher path of change is his/her the level of content knowledge, technological knowledge, or pedagogical content knowledge. For example, Yona had low level of chemistry content knowledge and she remained in the early stages of concern. Zohar, on the other hand, had high level in both of chemistry content knowledge and technological knowledge, enabling him to progress to the advanced stages of concern during the implementation period. The observations of the three case study teachers reinforced our understanding of individual teachers' concerns, justifying the need to analyze not only the group SoC profile, but also the individual SoC profile. Thus, before using CBAM, we recommend that the researcher considers whether individual or group profile is needed and which other research tools can be used for triangulation of the SoC findings.

Discussion and contribution

This study applied the CBAM framework as a diagnostic tool for examining chemistry teacher concerns and processes of change during the implementation of a new learning environment in the setting of reforming chemical education in both middle and high schools. When used in conjunction with other research tools it enabled us to tailor a specific profile of concerns, and to develop an in-depth analysis of the concerns of middle and high school chemistry teachers' concerns, providing benchmarks for comparisons, and suggesting alternative reasons for teacher behavior.

Middle and high school chemistry teachers' concerns while implementing TELE

Even though change is often challenging and slow to implement in educational practices in general, and in chemical education in particular (Hargreaves, 2005), it is important to promote practices that positively impact student engagement and develop their 21st century skills. A significant component of that change process is understanding and addressing teacher concerns related to innovation (Anderson, 1997; Hall, 2013; Chen and Jang, 2014). These concerns should be taken into account by the stake holders and the school system, which should provide adequate support and address the current concerns of teachers (Dori *et al.*, 2005). The data from the present study showed that at the beginning of implementation, HS teachers' concerns were multifocal, and focused on *personal* and *impact concerns*. After ten years of implementation, the intensity of the Awareness, Information and Refocusing concerns increased greatly. Through the interviews, we saw reinforcement of these results when teachers' expressed their difficulties in time management. The most common concern in the beginning of implementation for MS teachers was related to *personal concerns* and after a year of implementation we identified a different profile of concerns in each case study; one teacher remained in the early stages of concerns, another teacher was moving forward to the advanced stages of concerns, and the last teacher remained in the Refocusing stage and showed that she was moving towards a process of change. These findings about teachers' concerns both confirmed and contradicted prior work; as new and unexperienced users of the TELE, it would be expected that the early stages of concern such as Personal, Information and Management would be high in both groups of teachers (Hall *et al.*, 1977; Hall, 2013), but as a teacher becomes more experienced and skilled with the innovation, the intensity of stages expressed earlier will decrease while the intensity of advanced stages (Consequence, Collaboration, and Refocusing) will increase (Hall *et al.*, 1977; Hall and Hord, 2011; Dori *et al.*, 2005; Chen and Jang, 2014).

Profiling the process of change in teacher concerns

The CBAM framework underlines that change is a process rather than a simple and singular event (Fuller, 1969; Hall *et al.*, 1977; Hall, 2013). We addressed this assumption by examining HS teachers' concerns, and the process of change in their concerns, over a period of ten years, and at two points of time, and for MS teachers over a period of a year in three points of time.

We compared the SoCQ responses of HS teachers at the beginning of implementing TELE and after ten years of implementation. We expected that experienced users would reflect low concerns in the first stages, such as Awareness, Information, and Personal, and a high intensity of concerns in the advanced stages such as Collaboration, and Refocusing (Hall *et al.*, 1977; Hall, 2013). Surprisingly, the teachers who were familiar and skilled with the technology-enhanced learning environment after ten years of implementation continued to have multi-focal concerns. The intensity of *personal* – Awareness and Information, and *impact concerns* – Refocusing increased greatly. According to Hall and colleagues (1977), when experienced teachers show high intensity concerns regarding the Awareness stage, it is likely that they are more concerned with other aspects of their professional development than with the innovation aspect of their teaching. The teachers also emphasized this during their interviews, when they addressed the pedagogical aspect of teaching with technology and time-management issues. The dynamic and changing nature of teacher concerns and the transitions between the different stages are well documented in the literature (Kim and Baylor, 2008; Hall, 2013; Kwok, 2014). Dori *et al.* (2005) examined the dynamic and changing nature of teacher concerns and found that as teachers became more experienced and skilled with the technology, the intensity of stages expressed earlier decreases while the intensity of advanced stages (Consequence, Collaboration, and Refocusing) increases. Conway and Clark (2003), who examined teacher concerns while teaching in the context of an internship program, found that these concerns shifted from *personal* to *task concerns* and later to *impact concerns*. In our study, we noticed a different trend as the multi-focal concerns remained after ten years of implementation, but their intensity increased. The reasons for this profile might be that during their interviews, half of the HS teachers noted that the support from the Ministry of Education (MoE) in implementing TELE in general and CCM & CCL in particular was greatly reduced, and therefore they had not used it often over the ten year period. For example, Hila said: *Nowadays, there is not enough emphasis nor support to implement these environments* [CCM & CCL] – *both technically and in the national curriculum; dealing with the equipment and sensors is very time consuming because they don't always work; However, if I had support from the MoE I would invest the time in implementing these environments*. Another teacher, Niv, mentioned that: *The emphasis on preparing the students to the matriculation examination is much stronger and significant than the emphasis on implementing technology in school in general and CCM & CCL in particular*. These statements reinforce the claim that time management concerns, which HS teachers mentioned after ten years of implementation, were crucial when implementing TELE (Table 4).

We suggest two possible explanations for this trend: (1) technology integration needs to be emphasized more in the national curriculum; (2) teachers were exposed to the rapid technological advances and the emergence of new technological tools, which caused them to be concerned about personal aspects of integrating technology. They require teachers to be alert and constantly exposed to new technological environments. Teachers therefore need to be active in constantly pursuing professional development programs that can support them, and expose them to new technological advancements. Since technology is constantly changing, there is a need to encourage teachers to be updated and make them aware that participating in a PD about technology is not a one-time treatment for enhancing their skills in integrating technology (McCoy, 2001; Bate, 2010). This active approach can help in decreasing *personal concerns* and enabling teachers to concentrate on the impact aspects of the TELE.

When profiling the process of change for MS teachers, we saw that Yona remained in the early stages of concerns throughout one year of implementation, while Zohar and Sharon demonstrated a process of change and high Refocusing intensity. The dominance of the early stages of concerns while implementing technology is documented in the literature (Newhouse, 2001; Casey and Rakes, 2002; Schoepp, 2004). Both Newhouse (2001) and Casey and Rakes (2002) investigated the concerns of teachers at K-12 levels and found that even though all the teachers implemented the technology, the lower stages of concerns dominated to a great extent. They found that most teachers had high Stage 2, Personal concerns, and that the lowest concern intensity was in Stage 4, consequence. It is also very important to address *personal concerns*, especially if they remain high after a year of implementation. Usually teachers ask themselves how an innovation will affect their ability to implement it and what the costs and benefits will be for them. They are concerned about how technology will affect them and do not yet demonstrate any concern for the impact upon students. Prior research suggests that increased attention to students is an important component of developing the expertise needed for teaching (Sherin *et al.*, 2011). Researchers also found that a focus on student thinking is particularly critical for the successful implementation of education reform (Fuller and Bown, 1975; Carter *et al.*, 1987). This means that having *personal concerns* might inhibit teachers in focusing on the impact of the TELE on their students' learning processes. When implementing a reform, it is therefore important to take into consideration not only the ability of the teacher to implement technology, but also their ability to focus on their students.

The vertical alignment between middle and high school teachers

We propose a possible explanation for the differences in the findings between MS and HS chemistry teachers, which focuses on the gap that exists between these two communities in our country, in aspects of assessment and teacher knowledge. It is important to note that other explanations are also possible and given the qualitative nature of our study, further research is needed in order for the results to be more generalizable.

The concept of alignment involves teacher professional development, assessment, curriculum emphasis, learning materials, *etc.* (Porter *et al.*, 2007). Our research raises questions regarding the vertical alignment between middle and high school teachers with emphasis on assessment and teacher knowledge, calling for additional investigations in different settings and other countries.

Assessment aspect. In recent years, formative assessment and authentic assignments have been the focus of efforts by chemical educators to close the gap between research and practice (Szteinberg *et al.*, 2014). These efforts can be greatly facilitated by TELE, helping both teachers and students. When graduating from high school, students who choose to major in chemistry have to take the matriculation exam (similar to SAT in the US), which MS students do not have to pass. There is thus a need to align the national matriculation examination with reform in the scientific domains in middle schools. This examination was fundamentally changed after the reform became mandatory in high schools, and in middle schools this process is still in its early stages. It is therefore likely that MS teachers have not yet felt the urgency to adapt to the new reform and to implement the TELE setting in a significant way: Yona remained in her early stages of concern after a year of implementation and Sharon was reluctant to use the platform in her lessons. This difference may explain why the Refocusing stage (*impact category*) of HS teachers was of high intensity at the beginning of implementing TELE and after ten years of implementation. The impact of the new learning environment on the students was a high priority and it was important for the teachers to modify and improve the learning and teaching process by using TELE. In reviewing the literature, we did not find research which connects assessment methods with technology implementation concerns, but it is well-documented that assessment is a common barrier to integrating technology into the curriculum for instructional purposes (Hew and Brush, 2007). Bridging the gap between middle and high schools regarding assessment might help policy makers to encourage MS teachers to implement TELE into chemistry lessons in a meaningful way. Such a process of change will foster implementation of different pedagogical practices and prompt teachers' *impact concerns*.

Teacher knowledge. High school chemistry teachers teach students who choose to major in chemistry in advance level and therefore the Ministry of Education set a standard of a MSc or at least BSc in chemistry and a teaching certificate in chemical education. MS teachers previously (before the reform) taught general science to all students, and chemistry was integrated into the existing curriculum. As a result of the reform, these teachers taught chemistry specifically, with teaching hours dedicated to chemistry. Teaching general science in middle schools brought a diverse population of teachers with different educational backgrounds, not necessarily in chemistry (in our research 50% of the teachers had a biology background and 50% chemistry). For example, Yona's content knowledge of chemistry was low, as her main educational background was biology. She also had difficulties operating the system and her technological knowledge was low. She was thus less concerned about the impact of the innovation on the students' learning processes and more concerned about its effect on her personally, as a teacher. On the other hand, although Zohar was a novice teacher, he had a strong content knowledge in chemistry, he managed to adapt his pedagogical practices with technology and use multiple technological tools. After a year of implementation Zohar showed progress to the advanced stages of concern.

HS teachers were mostly very experienced chemistry teachers with educational background in chemistry, who prepared students for the matriculation exam, and both their content knowledge and pedagogical content knowledge were high. We therefore suggest that teacher knowledge, such as content and technological knowledge, might influence teacher concerns and consequently influence the implementation of technology. Teacher knowledge is also a common barrier when implementing technology (Blanchard *et al.*, 2009; Chai *et al.*, 2013). The connection between the ability to teach subject matter through technology and to combine the relevant pedagogy is noted in Chai *et al.* (2014), who called for an examination of the interaction between the knowledge of technology and the knowledge of subject matter (Mishra and Koehler, 2006). We suggest adding teacher concerns as another aspect of this type interaction as mentioned by Chai *et al.* (2014) and focus on teachers' knowledge since it might inhibit their ability to implement TELE in a significant way during chemistry lessons. TELE is also crucial for meaningful understanding of chemistry. It can provide multiple representations and visualization solutions (Wang and Hannafin, 2005; Dori *et al.*, 2013) and help students and teachers transfer between the chemistry understanding levels, such as the phenomena, the particulate nature of matter, the symbol, and the process (Dori and Sasson, 2008; Dori and Kaberman, 2012). We thus emphasize that it is important to investigate the concerns of chemistry teachers.

In summary, our data showed that the profiles of the concerns of middle and HS teachers are different, and evolve over time differently. We assume that these differences are rooted in the gap that exists in teacher content knowledge, pedagogical content knowledge, and assessment between MS and HS teachers. Given these results, we recommend that professional development programs be tailored to each group of teachers with regard to their concerns and knowledge, as well as establishing a community of practice of both middle and HS chemistry teachers with a common vision to improve chemical education at both levels.

Research limitations and strengths

This research has two primary limitations. First, we investigated a small number of participants that were representative of the northern region of Israel but not all the chemistry teachers. Second, the comparison between MS and HS teachers was conducted in different time frames while using and implementing different technological learning environments. However, this was unavoidable, because the HS reform took place about a decade prior to the MS reform. On the strengths side, our research is unique in its longitudinal nature. Following teachers from both MS and HS enabled us to examine how these teachers coped with adapting to concurrent reform and technological environment. Additional strengths are described next.

Insights into the theoretical model of CBAM

Using CBAM as the theoretical framework of our research allowed us to gain important insights into the implementation of the model and later the analysis of the data. Based on our experience in this research, we recommend using CBAM in combination with additional research tools, such as interviews and observations, which provide in-depth understanding of the teachers' concerns. This approach will assist the researcher in building teacher profiles and characterize the process of change they experience. According to the CBAM model (Hall, 1976, 2013), SoCQ is often used for differentiating between users and non-users of the innovation. Non-users have high intensity in the first stages of concerns (0–3) and users have low intensity in these stages and high intensity in the later stages of concerns (4–6). In our research, we found that users of the innovation, who were HS teachers after ten years of implementation and MS after one year of implementation, experience high intensity also in the first stages of concern. Therefore, the additional research tools might shed light on the reasons that increase the teachers' concerns, since during the implementation of innovation, sometimes the personal aspects of a teacher or a group of teachers can play a major role.

We realized that when the demographic characteristics of the teachers are different and the group of teachers is heterogeneous, it is necessary to analyze the SoCQ data both as a group and individually. We also analyzed the observations and interviews of several case studies of teachers with different levels of TELE implementation. In conclusion, our research suggests a specific dimension for coping with changes by profiling and characterizing teacher concerns, both as a group and as individuals. Findings based on the CBAM as a diagnostic tool can thus serve as the first step toward understanding the process of change that teachers experience, and their concerns while implementing an innovation. We showed how CBAM might differentiate between teachers with different qualifications, experiences, and concerns in diverse teaching situations in both MS and HS. Such diagnosis can help stakeholders in the education system, such as school administrators and change facilitators, to develop specific interventions and activities for different groups of teachers based on specific concerns while implementing TELE. Further research like that presented here is also needed in other disciplines, such as biology and physics and in other countries and cultures.

Appendix 1

The *Wired for Chemistry* module is designed for students in middle schools, is based on Learning Content Management System (LCMS) named Lnet¶ that includes chemistry content, and computerized activities and teachers' tools for managing students' learning. The activities are based on simulations, short films, computerized molecular models and interactive on-line learning.

Teaching and learning *via* the Lnet platform promotes students with interaction in TELE as well as active learning. Students are encouraged to gain content knowledge and skills, such as meaningful learning *via* the four chemistry understanding levels; data processing; representations and analysis of information; learning chemistry in the context of everyday life; and responding to on-line assignments.

The main chemistry topics in the *Wired for Chemistry* module are: (1) chemical bonds, (2) chemistry of carbon compounds and the uniqueness of the carbon atom, and (3) materials and their impact on people, the public and the environment.

In Fig. 7 we can see a 3D structure of a graphite compound which the student can rotate and explore from different angles.

Afterwards, the students explore more allotropic compounds such as fullerene and carbon nano-tubes by watching a short video about their characteristics and applications in everyday life.

Another example of an assignment is related to the topic of *materials and their impact*, in which students are asked to read an adapted article focused on life cycle of glass and respond to a few questions. Fig. 8 presents a diagram of the life cycle of a glass bottle. The students are expected to transfer the information provided in the text to the diagram. As the students' progress, they are requested to discuss with their peers reasons for choosing a specific product such as glass, plastic or aluminum and elaborate on why they chose it.

Fig. 7 Graphite 3D structure (the instructions in Hebrew are translated below).

¶ http://lnet.org.il/

Fig. 8 Life cycle of a glass bottle (the instructions in Hebrew are translated above).

Appendix 2

The *Taste of Chemistry* module implemented components of the technology used in the case-based and inquiry-based computerized laboratory (CCL) along with web-based assignments and computerized molecular modeling (CMM).

CMM is a piece of computer software that aids in graphically representing complex molecular structures. The use of CMM allows viewing the spatial structure of the molecular model and switching among different representation modes: framework, ball-and-stick, and space-filling (Dori *et al.*, 2005; Kaberman and Dori, 2009). CCL integrates computerized desktop experiments with sensors and real-time data collection. A computerized laboratory includes digital probes such as pH monitors which integrates with software that facilitates data representation and analysis (Dori *et al.*, 2004; Dori and Sasson, 2008).

The main topics and characteristics of the module are presented in Fig. 9.

As Fig. 9 shows, students were engaged in planning and carrying out computer based laboratory investigations, analyzing and interpreting data, and constructing and using models. Student learning outcomes were assessed accordingly.

Table 6 presents examples of different types of technology-based assignments in this module using the CCL and the CMM tools.

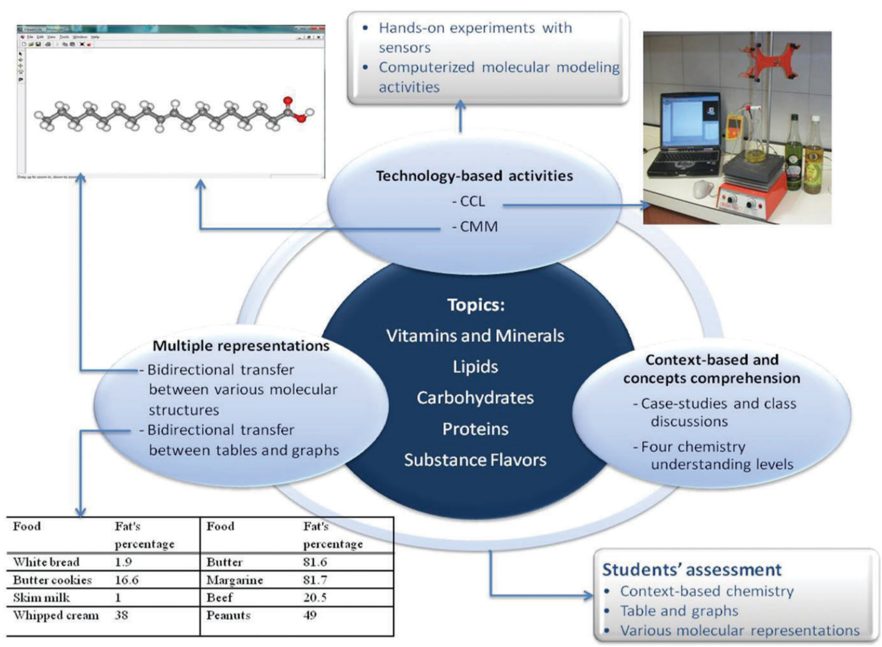

Fig. 9 Topics and characteristics of the *Taste of Chemistry* module.

Table 6 Examples of technology-based assignments in the taste of chemistry module

Assignment's purpose	Assignment' main thinking skills
Constructing a model of oleic fatty acid and studying its chemical structure	• Constructing a computerized model of an oleic fatty acid using frame and ball and stick model types. Students need to convert chemical formulae into two types of structural models. • Studying the spatial structure of a molecule and its rotation around a single and double carbon–carbon (C–C) bond. • Constructing a model of an oleic fatty acid using 3-D computerized modeling. • Studying the spatial structure of the molecule and length of single and double C–C bonds. • Summarizing all the characteristics of the chemical structure of an oleic fatty acid.
Studying the connection between olive oil types (extra-virgin and virgin) the percentage of free fatty acids (FFA) in the oil	• Formulating a suitable research question, defining the dependent, independent, and control variables. • Conducting an acid–base titration of extra-virgin olive oil (dissolved in ethanol) by sodium hydroxide solution, using pH sensors and connecting them to the data collection apparatus. • Repeating the titration with virgin olive oil. • Calculating the percentage of FFA based on the two titration curves. • Drawing conclusions and raising a new research question for farther inquiry.

Appendix 3

Table 7

Table 7 Interview protocol

Aspect	Questions
Technology usage	Are you implementing technology in the classroom and to what extent? How are you implementing technology and what are the technological tools you use? Please explain. Has there been a change over the last decade in the way that you implement TELE in the classroom? Please explain (only for HS teachers).
Facing challenges while implementing TELE	What difficulties did you encounter when implementing technology in classroom? How did you cope with them?
Advantages in implementing TELE	What advantages did you find while teaching with technology

Appendix 4

Tables 8 and 9

Table 8 The mean and std. deviation for HS teachers stages of concern in the beginning of implementing TELE

Stage of concern	Mean	Std. deviation
Awareness	0.9	0.166
Information	2.6	0.562
Personal	3.5	0.682
Management	3.1	0.348
Consequences	4.5	0.493
Collaboration	4.8	0.407
Refocusing	3.9	0.619

Table 9 The mean and std. deviation for HS teachers stages of concern after ten years of implementation

Stage of concern	Mean	Std. deviation
Awareness	0.9	0.166
Information	2.6	0.562
Personal	3.8	0.755
Management	2.5	0.832
Consequences	4.2	0.629
Collaboration	5.1	0.503
Refocusing	4.6	0.772

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