Science Education International
Vol. 25, Issue 2 (Special Issue), 2014, 186-206

Developing in-service science teachers' ownership of the PROFILES pedagogical framework through a technology-supported participatory design approach to professional development

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ABSTRACT: Teacher ownership is crucial for the sustainability of science education reform efforts. This paper discusses participatory design as a bottom-up approach for promoting teachers' sense of ownership of inquiry-based learning and teaching approach as put forward by the PROFILES project. According to the prevalent argument in favor of participatory design, this approach leads to designs that are ecologically valid and attuned to different stakeholder needs. In this study, we report on the investigation of a technologically-mediated approach of participatory design of inquiry-based learning. Research questions address the teachers' perceptions of the affordances and trade-offs of the participatory design approach, and its effect on teacher design efforts and on student motivation. We collected qualitative data from 26 teachers and quantitative data from 171 high school students. Teachers reported that the process of collaborative design and the enactment of the designed module increased their ownership towards the PROFILES module. The analysis of nine chemistry teachers' discourse revealed that this process allowed them to collaborate productively, resulting in the development of a module that adopted the PROFILES 3-stage philosophy and was more aligned with their students' needs. The analysis of students' surveys indicated a statistically significant increase in motivation. These findings suggest that technologically-mediated participatory design is a valid approach for promoting teacher ownership of the PROFILES approach in science teaching.

KEY WORDS: Participatory design, Teacher Ownership, Technology-supported professional development, Science education, PROFILES

INTRODUCTION

Inquiry-based learning can support students' scientific literacy (American Association for the Advancement of Science [AAAS], 1993; Eurydice network, 2011; U.S. National Research Council [NRC], 2012). Despite a broad support of inquiry in educational policy documents around the world, it appears that teachers are reluctant to adopt inquiry-based practices, thus jeopardizing the successful implementations of reform

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efforts. At the same time, researchers emphasize that curriculum reforms are successfully implemented in schools only when educators develop a sense of ownership of the reform, namely a sense of being co-owners and co-architects of such reform approaches (Brown & Campione, 1996; Fullan, 2007).

This study explores participatory design as the context for developing in-service science teachers' sense of ownership, in the belief that participatory design can increase teacher ownership of reform efforts and support educational change. Participating in the design of a learning environment allows teachers to design activity sequences that address their students' needs, while also providing teachers with a flexible understanding of the relationship between instructional goals, student activity and desirable learning outcomes. In a review of the literature, Keys and Bryan (2001) concluded that the topic of teachers' participatory design, and subsequent implementation cycles, had been largely unexplored despite its capacity for a more ecologically valid and, potentially, a more sustainable approach to reforming educational practice. In prior work conducted by our research group we explored the topic of participatory design with a small group of in-service teachers. Given the positive results of this work (Kyza & Nicolaidou, under review), we extended our investigation to include a larger number of teachers (n=26) to explore a technologically-mediated approach of participatory of extended, inquiry-based learning environments.

The present study was conducted in the context of the European project PROFILES - Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science (Bolte, Holbrook, & Rauch, 2012). The main emphases of the PROFILES project were (a) science education as a strategy to promote responsible citizenship and scientific literacy (Holbrook & Rannikmae, 2007) and (b) a bottom-up approach of in-service science teachers' continuous professional development (CPD) (Blonder, Mamlok-Naaman, & Hofstein, 2008). While PROFILES partners across Europe employed diverse approaches to support a teachers' bottom-up approach to CPD, this study investigated the participatory design approach adopted by our research group as a viable and productive model for in-service science teachers' professional development.

The overarching goal of this study was to investigate a technology-supported form of participatory design and explore whether this approach can support scaling up to include multiple teacher design teams. Situated in a design-based context of iteratively refining our participatory design professional development model, we investigated teacher perceptions, participatory design discussion themes and the impact of collaborative designs on a subset of the teachers' students. As a result, we focused on the following research questions:

1) What were the affordances and trade-offs in the design of the technology-supported continuous professional development (CPD) approach, as identified by the participating teachers?
2) What were the main issues that teachers grappled with during the design sessions?
3) To what extent was the participatory design approach successful in creating meaningful inquiry learning environments for the students?

The answers to these questions provide useful insights on the topic of participatory design as a model for technology-supported professional development of in-service science teachers.

THEORETICAL FRAMEWORK

Inquiry-based learning has been at the heart of efforts to reform science education for the last decades (NRC, 2012; AAAS, 1993; Osborne & Dillon, 2008). However, a recurring finding in many educational reform efforts is that imposed attempts to reform education are generally problematic; the adoption of "top-down" approaches, in which reforms are imposed by central agents expecting teachers to just employ the policy makers' ideas, is doomed to fail (Brown & Campione, 1996; Hofstein, Mamlok-Naaman, & Carmeli, 1997; Mamlok-Naaman, Hofstein, & Penick, 2007, Yamagata-Lynch, 2003). Researchers suggest that innovations are successfully accomplished only when teachers feel that the innovation belongs to them (Pintó, 2005; Pintó, Couso, and Gutierrez, 2005).

Participatory Design and Teacher Ownership

Pintó, Couso, and Gutierrez (2005) highlighted the significance of ownership, arguing that only if teachers develop a sense of ownership towards an innovation, such as PROFILES, will they effectively integrate it into their lessons. Participatory design is a common practice outside the field of education and aims to involve the users of a product, or of a system in the design process, in order to maximize the usability and effectiveness of the design; this approach promotes active participation of users in the design phase, as well as in the decisions that will affect them (Berns, 2004; Kensing & Blomberg, 1998). Re-contextualizing this process in the domain of science education, participatory design refers to initiatives which place science education teachers as active participants in the design, or in the adaptation of learning activities.

The participatory design approach acknowledges that teachers are key agents of educational change, and thus, repositions teachers from transmitters of knowledge to designers of students' learning (Mor, Warburton, & Winters, 2012). This approach shortens the distance and creates common ground between the users and the system designers (Chin Jr., 2004), or, in our case, between the teachers and the policy makers, allowing science teachers to gain insights into and to become co-owners of the reform efforts. Participatory design encourages users to adjust the design according to their needs and their practical circumstances, thus resulting in high levels of product usability and end user acceptance (Damodaran, 1996). As a result, participatory design can allow teachers to design educational materials that are better aligned with their students' expectations, as well as with their own teaching needs.

Although the participatory design approach is promising, studies investigating the potential of this approach to support teachers' interactions to collaborate for the design of a learning environment, or of the impact of such a learning environment on students' learning, are limited. Kyza and Nicolaidou (under review) investigated the participatory design approach with a small group of teachers. Their approach included face-to-face group meetings with 3 teachers engaged in cycles of design and enactment of a web-based learning environment. The teachers reported that this approach supported the developing of their understanding of inquiry learning and of the role of scaffolded, web-based learning environments to support secondary school students' science learning. In addition, the analysis of students' performance during the enactments using a pre-posttest design yielded statistically significant results (Nicolaidou, Kyza, Terzian, Hadjichambis, & Kafouris, 2011). However, professional development programs usually address larger cohorts of teachers; in-service teachers, in particular, are challenged with the participation in such programs as they try to balance professional and personal obligations. In a study of a professional development program aiming to support the integration of technology in the curriculum, Yamagata-Lynch (2003) found that the professional development program presented several challenges to the participating teachers and complicated their already hectic schedules.

Several questions emerge from the studies reported in this brief review, relating to: whether the participatory design approach to professional development can be employed with a larger cohort of teachers; how this process can be orchestrated to facilitate teachers' involvement while removing tensions; and whether this process can actually benefit student learning and engagement. It is these issues that are at the heart of the present study.

METHODS

Participants

The study took place in the context of the PROFILES continuous professional development program in Cyprus, which employed a collaborative and participatory design model to enact science teachers' professional development. Twenty-six teachers and 171 secondary school non-science major students participated in this study. In this participatory design-based professional development model, teachers formed four discipline-based groups (Biology, Chemistry, Elementary Science Education, and Physics). Each teacher group engaged in the collaborative design and subsequent enactment of inquiry science learning environments which adopted the PROFILES approach within their classrooms over the period of one academic year. Teachers volunteered to participate.

Instructional Context

Technology support.

To ameliorate the anticipated tensions due to the teachers' busy schedules, we employed a suite of technological tools to support teachers' continuous professional development. A combination of synchronous and asynchronous communication tools were used to support constant access to information and increase teachers' capacity to participate in the design of each disciplinary team. These web-based tools consisted of the online STOCHASMOS learning and teaching platform (Kyza & Constantinou, 2007), which was used by the Chemistry science educator group for the authoring of their PROFILES-based learning environments, an asynchronous communication platform, and a video conferencing system. STOCHASMOS (http://www.stochasmos.org) is a scaffolded environment that enables teachers to assume a more active designer role, and provides computer-based scaffolding to support students' reflective inquiry-based investigations. In that way, the platform allowed chemistry teachers to upload data online and develop scaffolding structures, such as data pages and explanation frameworks to guide student inquiry and decision making processes. The web-based, asynchronous communication platform provided a virtual space to share resources, while the web-based video conferencing system allowed richer interactions during the synchronous video meetings. In addition, the STOCHASMOS platform supported the development of scaffolded inquiry PROFILES-based modules. This combination provided a more facile communication of ideas, helped coordinate the design process and supported teachers' collaborative reflection.

Hybrid participatory design communication structure.

The participatory design model we adopted included face-to-face and web-based communication. Based on prior professional development experiences, we selected tools that could afford richer experiences of communication and collaboration and which could extend the face-to-face meetings. Each disciplinary design group had a minimum of seven face-to-face meetings during after-work hours, four of which included across group discussions and group working sessions. Disciplinary groups also scheduled additional face-to-face groups individually. In addition, each disciplinary group had several video-conference planning sessions, which ranged from 3 to 7 sessions, with a minimum duration of 60 minutes each. A member of the local PROFILES team was present during each meeting, keeping minutes, facilitating the discussion, identifying needs and summarizing the decisions after the meeting, thus acting as a liaison between the researchers and the teachers.

The PROFILES 3-stage design model. All teachers participating in the PROFILES local team were introduced to the PROFILES education through science framework (Holbrook & Rannikmäe, 2007) and the 3-stage PROFILES model for the development of the learning module (Holbrook & Rannikmae, 2010). According to the 3-stage PROFILES model, the design process should be based around the development of a module which (a) has a relevant, motivating socio-scientific scenario, (b) engages students in meaningful inquiry activities that relate to the socio-scientific scenario, and (c) requires that students engage in decision making to respond to the questions introduced by the socio-scientific scenario.

Data Collection

Both qualitative and quantitative data were collected for this study depending on the nature of the research question. To investigate the teachers' perceptions of the affordances and trade-offs of the technology-supported participatory design approach (Research Question 1, RQ1) we collected survey data from twenty-six, in-service science teachers who participated in the program over the period of one academic year (September-May). To investigate the main discussion themes during the professional development program (RQ2), we focused on one of the four disciplinary teacher groups and collected qualitative data from the asynchronous and synchronous discussions of one design group consisting of nine chemistry teachers. Finally, to investigate the effectiveness of the participatory design approach in relation to student learning (RQ3), we collected data from the students of the chemistry teachers (n=171). As not all of the teachers who participated in the design of the learning environments enacted the unit, only those students of the enacting chemistry teachers were used in the analyses for RQ3.

Data Coding and Analysis

We next present the coding process of the data collected per research question.

RQ1: Affordances and trade-offs of the participatory design approach. Data regarding teachers' perspectives about the participatory design approach were collected through an open-ended questionnaire, administered to 26 science teachers who participated in the full cycle of the professional development program. Teachers were asked to report on the advantages and disadvantages of the process and discuss the main factors which had a negative or a positive impact on their participation. In addition, teachers were asked to discuss their preference for a design-based approach versus the use of an already developed module. The responses to the participatory design questionnaire were qualitatively analyzed, employing the Attride-Stirling's (2001) thematic network analysis. According to this analysis, the teachers' responses were iteratively read and coded according to emerging topics, leading to 10 codes. A list of the issues discussed in each code was also created. Following this process, codes were organized into basic themes, which were eventually grouped in two organizing themes that highlighted the factors that affected the teachers' participation in the design process.

RQ2: Participatory design discussion themes. Data, regarding the nine chemistry educators' participatory design group, were collected from the teachers' asynchronous online conversations over a period of six weeks and from two synchronous web-based meetings lasting two hours each, using an online video-conferencing platform. The participatory design meetings were recorded and fully transcribed. The discussions were merged with teachers' asynchronous conversations. The emerging data corpus was analyzed in a two phase analysis (Patton, 2000), focused on teachers' utterances and used an open coding approach without any predetermined categories. As a result of the coding, a number of main themes were identified and labelled as the core themes discussed. In the next step of the analysis, these main themes served as categories for structuring the data corpus. In addition, excerpts were identified to highlight the importance of the different aspects that the chemistry teacher design group discussed while developing a PROFILES module in order to motivate their students to learn science.

RQ3: The effectiveness of the designs in creating motivating learning environments. To investigate the third research question, we collected quantitative data from the enactment of the chemistry module from a total of 171 high school students (82 boys and 89 girls) in five different public schools. The data were collected using the MoLE motivation instrument (Bolte, 2012) which was administered to the students before and at the end of each enactment. The administration of the instrument provided student motivation data on the PROFILES learning environment employed, as these compared with students' experiences in previous chemistry lessons. The MoLE instrument scales addressed: (1) Comprehensibility of the taught material, (2) Opportunities to participate, (3) Relevance to everyday life provided by the socio-scientific contexts, (4) Class collaboration, (5) Students' willingness to participate and (6) Student satisfaction. A seven point rating scale (where 1 was the minimum and 7 was the maximum) was employed and students were asked to evaluate the aforementioned scales in the two different conditions (inquiry-based design and traditional chemistry classes). The quantitative data collected were analyzed via t-test paired sample tests.

FINDINGS

Affordances and trade-offs of the technology-supported participatory design

One of the goals of this study was to investigate whether a technology-supported design approach to continuous professional development could be successfully implemented with a larger cohort of teachers. In their responses to a questionnaire asking them to discuss the advantages and disadvantages of the participatory design approach to professional development, the participating teachers referred to the collaborative and supportive context in which they worked, while stressing how motivated they felt and how much they learned during this process. At the same time, the teachers identified challenges to this professional development approach, which can inform future design efforts. The themes of the teachers' reports were grouped in two main areas and are summarized in Table 1.

More specifically, as the teachers explained, the participatory design process afforded the exchange of different perspectives, encouraged critical constructivism and facilitated the distribution of the workload. In addition, the teachers highlighted how much they learned during the participatory design process, explaining how it promoted learning about new teaching methodologies as well as learning about the employment of new technologies. The teachers explained that they felt motivated by participating in the development of modules aiming to enhance the motivation of traditionally non-engaged students, as well as by the novel and challenging nature of the CPD. Last, but not least, the participants highlighted that the PROFILES design framework, as well as the PROFILES support team, guided and supported their actions.

Table 1: Teachers' views of the affordances and constraints of the participatory design approach

Organizing Themes	Basic Themes	Issues discussed	Codes	f
Factors that positively affected teachers' participation	Advantages regarding the process	Exchange of ideas	Collaboration	21
		Critical constructivism		
		Distribution of workload		
		Scaffolding by the PROFILES design framework	Supporting framework	11
		Scaffolding by the researchers		
		Learning about new teaching methodologies	Learning experience	6
		Learning about new technologies		
		Challenging and novel process	Motivating experience	6
		Motivated by the development of engaging modules		
	Advantages regarding the final product (module)	Compatibility with the curriculum topics and approaches	Compatibility	3
		Compatibility with the students' needs		
		Deep understanding of the module and its aims	Ownership	9
		Familiarization with the module / More effective teaching		
Factors that negatively affected teachers' participation	Disadvantages	Each stage of the designing process was demanding	Time-consuming	19
		Delay due to lack of immediate communication		
		Delay due to polyphony and lack of agreement		
		Delay due to lack of timetables		
		Insufficient coordination, especially in large groups		
		Lack of work plan and clear allocation of responsibilities		
		Disagreements and difficulties in group decisions		
		Difficulties in arranging face to face meetings	Communication problems	10
		Web-based communication not always effective		
		Unequal involvement	Unequal contribution	8
		Different pedagogical content knowledge		
	Personal Issues	Lack of time	Busy schedule	16
		Overloaded schedule		

On the other hand, when discussing the disadvantages of the participatory design model, teachers referred to the time-consuming nature of the process, to communication problems as well as to the unequal contribution of the participants. First, as the teachers explained, despite the demanding nature of the whole process, there were several delays due to the lack of immediate communication, polyphony and lack of agreement. Teachers stressed the need for agreeing on timetables which can guide the design process. Differences in the degree of participation and the participants' varied pedagogical content knowledge, created a sense of inequality regarding the contribution of each teacher to the development of the PROFILES modules. Finally, as the teachers explained, personal issues, such as their own busy schedules, hindered their active participation during the design process.

All science teachers indicated that despite the voiced concerns, they would prefer to participate in the design of a PROFILES module, instead of teaching a module which was simply handed to them. As they explained, the implementation of modules that were developed by themselves could have a more positive impact on students' learning, since, in such a case, the teachers understood the design principles and teaching implications of these modules better. Hence, according to the teachers' views, the design-based approach to professional development allowed them to become more familiarized with the PROFILES modules, and thus enabled them to implement these modules more effectively. In addition, the teachers advocated the effectiveness of this design-based approach since, as they explained, these modules were not only compatible with the local curriculum, but also took into account the classroom settings and, thus, were much more tailored to their students' needs.

Participatory design discussion themes

We next analysed the discussions of one of the teacher design teams (chemistry educators design group, n=9) to provide insights into the professional development themes, which emerged during the synchronous and asynchronous discussions. The analyses of these discussions indicated that the participatory design process allowed the teachers to collaborate productively. These meetings supported teacher decision-making regarding the design of the learning environment, as well as practical issues (such as coordinating and distributing individual design assignments). The analysis of the chemistry group's discussions during the design of the module showed that the discussions focused on the following six themes:

(1) Development of a motivating socio-scientific scenario
(2) Learning goals of the module
(3) Focus of the module

(4) The PROFILES 3-stage inquiry process
(5) Technology integration, and
(6) Students' culminating decision-making task.

Figure 1 summarizes the six core themes and sub-themes discussed. All of these themes relate to each other, but dotted lines are employed in order to indicate that some of these themes were more strongly interconnected.

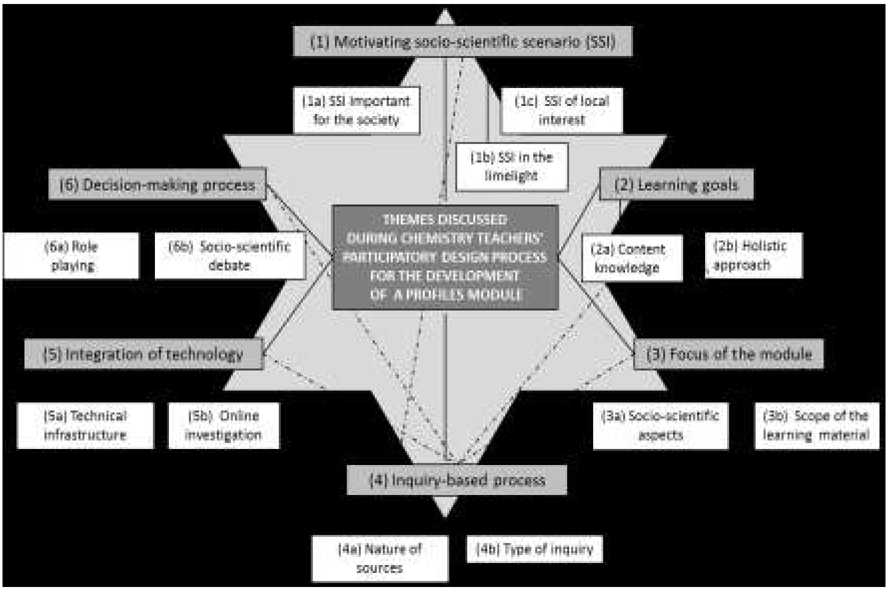

Figure 1. The six main themes and sub-themes discussed by the chemistry educators' design group during the participatory design process of a PROFILES module.

Discussion theme 1: Motivating socio-scientific scenario (SSI).

The chemistry teachers focused on deciding on an appropriate socio-scientific issue (SSI) in order to develop a motivating scenario for their students. The issue of student motivation was of paramount importance to teachers, as in the past, they had struggled to motivate non-science majors to actively participate in chemistry lessons. As a result, the teachers' discussions were initially devoted to the design of a locally important decision-making scenario, with the group concluding with the discovery of natural gas in Cyprus. As shown in the following excerpts, teachers discussed the connection of motivation to the scenario, highlighting the importance of the issue for the local society and the citizens.

> *Teacher 1: "Such a module will activate our students' interest with certainty, since we are talking about an issue that is in the limelight and we are bombarded about it every night on the TV news. Natural gas will affect Cyprus through a handful of different and important aspects such as: economics, politics, environment and society."* Excerpt A (asynchronous online discussion).

Discussion theme 2: Learning goals.

The teachers discussed the learning goals that the PROFILES module should accomplish extensively. Their discussions focused on whether the module should promote pure content knowledge about natural gas, or whether it should follow a more holistic approach, also targeting students' scientific skills and attitudes. Overcoming their initial disagreements, teachers reached the conclusion that a module that could target the promotion of knowledge and the enhancement of students' skills and attitudes would be more inclusive and desirable.

> *Teacher 2: "By the end of the module students should be able to know about the composition of natural gas [...] to be able to relate the composition of natural gas to its uses and its qualities [...]"*

> *Teacher 1:"I would also like to share my thoughts […] Students should also be able to support their thoughts with arguments, to make evidence-based conclusions and to resolve problems." Excerpt B (asynchronous online discussion).*

Discussion theme 3: Focus of the module.

Another issue that occupied a great amount of teachers' discussions related to the exact socio-scientific issues that should be included in the module and whether the module should have a broader scope including information about other fossil fuels, such as petroleum. Many of the chemistry teachers supported the notion that the module should focus exclusively on the impact of natural gas on a set of different socio-scientific dimensions (environment, economy, everyday life, and politics). However, during the design process, teachers decided to limit the focus of the module, highlighting only the impact of natural gas on the environment and everyday life, since a module with broader scope would not be feasible, due to the limited time that could be devoted to the teaching of this unit. One other criterion for their final decision was that these aspects were more aligned with their own expertise and thus, it would be much easier for them to develop the inquiry-based activities and to guide their students during the investigation.

Teacher 3: "In my opinion we should be more specific. We don't have much time and thus we cannot expand to cover many issues. [...] Personally, I have some doubts about expanding on issues such as the society or the economy. Besides, beyond discussing these issues with the students, how could we frame them into a learning activity?" Excerpt C (asynchronous online discussion).

Discussion theme 4: Inquiry-based process.

The teachers' discussions focused on the nature of data that should be provided to their students as well as the type of the inquiry-based investigation. These discussions were scaffolded by the affordances of the web-based platform used to develop the learning environment, which emphasized data-rich investigations and a reflective inquiry approach to support students' development of evidence-based explanations. More specifically, teachers identified natural gas data and its chemical properties (e.g. what is it, what are its main properties) as well as data on the socio-scientific aspects of the investigation (e.g. the impact of natural gas on the natural environment). In addition, taking into account the limited allotted time for chemistry lessons in the local curriculum, the teachers decided that the inquiry-based investigation should be structured according to the jigsaw approach (Aronson, 1978). The teachers discussed the advantages of using this method, pointing out that it would help save valuable teaching time, it could decrease students' cognitive load by reducing the learning material that should be covered, and at the same time it could promote student collaboration.

Teacher 1: "I have a suggestion... Let's combine methods. Initially, we could follow an approach according to which we could help the students to achieve a shared background (about natural gas). [...] After that, we could divide them in different working groups. Therefore, we could combine two different approaches for the same learning environment." Excerpt D (asynchronous online discussion).

Discussion theme 5: Technology integration.

The teachers' discussions on the integration of technology focused on the available technical infrastructure in their classrooms and on how to scaffold students appropriately. Highlighting their belief that integrating technology could motivate student participation, the teachers decided to carry out their lessons in a computer lab, a departure from their traditional teaching methods, which did not include the use of computers other than for presenting materials to students. In addition, teachers discussed the advantages and disadvantages of involving their students in a less structured web-based investigation in comparison to their more structured teaching methods and the guided inquiry-based approach. Taking into consideration the limited available time, as well as the composition of their classes, which consisted of non-major chemistry students, teachers preferred to design a guided inquiry learning environment using the STOCHASMOS web-based platform.

> *Teacher 2: "As far as the inquiry-based data are concerned, based on my previous experience when my students participated in open inquiry, they mentioned that when they were reading the information online, they struggled to understand the text and to make sense of it. To put it otherwise, in many cases they were afraid of the web pages. Therefore, I believe that it would be really useful to find the material that needs to be gathered, in order to adapt and to simplify where needed."* Expert E (asynchronous online discussion).

Discussion theme 6: Students' culminating decision-making task.

The nature of the decision-making task to support students' evidence-based decision making was a main area of discussion during the design sessions. As a result, teachers focused on the adoption of two strategies: role assignment and a socio-scientific debate. The teachers decided to divide the students into two main inquiry groups: the advocates, who should focus on examining the advantages of the natural gas, and the prosecutors, who should focus on the disadvantages of natural gas. In addition, teachers decided to conclude the lesson with a debate between the two inquiry groups, encouraging students to work on their arguments in their separate groups. These arguments were then presented to the whole class and were complimented with a discussion that helped students reach a more balanced decision regarding natural gas.

> *Teacher 4: "I think that this (the role assignment) is really a smart idea… It would be motivational for them to be more involved with their investigation, both for the advantages as well as for the disadvantages of the natural gas. It would seem like a challenge for them. […] And in the final debate they would come to discuss their findings. In the end they would have a chance to present the work they have done by supporting their arguments."* Expert F (asynchronous online discussion).

To what extent did the participatory design approach create meaningful learning environments for students?

The analysis of our data indicated that the participatory design process engaged teachers in productive discussions about the design process and key issues of inquiry learning relating to the nature of the inquiry activities, such as the selection and relevance of topic, identification and adaptation of data, student inquiry processes, etc. By the end of design process, the teachers had a usable product consisting of a web-based, inquiry learning environment designed to motivate student engagement with a data-rich investigation on natural gas. The learning environment targeted students' conceptual understanding about natural gas as a fossil fuel and the development of students' scientific inquiry and decision-making skills. The module developed:

i. Was based on an authentic scenario (the discovery of natural gas in Cyprus) as an event of local interest.
ii. Was designed to promote students' active involvement with a web-based, data-rich inquiry investigation: Students were asked to work in pairs in order to collect information about the natural gas, pursuing questions about its impact on everyday life as well as on the natural environment.
iii. Sought to promote students' engagement in a decision-making process.

A related question of interest was whether the end design would also be appealing to the students, for whom the curriculum was designed. We investigated this topic with the MoLE (Bolte, 2012) motivation survey; the analysis of students' responses to the MoLE yielded statistically significant differences between the two comparison situations (inquiry vs. traditional chemistry teaching approaches), since students considered the inquiry-based lessons as more motivating when compared to past teaching methods. Table 2 presents the results of the statistical analysis. As shown in this table, students who participated in the enactments of the web-based inquiry lessons designed by their teachers reported that they understood and enjoyed the lesson, felt that they had more time to think before answering a question, had more opportunities to make suggestions and questions, invested more effort, participated and collaborated with other students to a greater extent, and found the topic of instruction more relevant to their lives. These differences were statically significant, both overall as well as regarding each of the six sub-scales.

Results support the argument that the inquiry-based learning environment that was designed and implemented by the PROFILES chemistry educators design group motivated students who reported favorably on the departure from traditional chemistry lessons through which students used to be taught.

Table 2: Descriptive statistics and t-tests on comparing students' motivation between the past approaches to teaching chemistry (PAST METHODS) designed by the chemistry group educators and inquiry-based lessons (INQUIRY)

	PAST METHODS		INQUIRY		t-test	df
	M	SD	M	SD		
Total	4.37	1.06	5.27	0.94	-11.82**	148
Comprehensibility	4.60	1.41	5.36	1.09	-7.66**	152
Participation	3.81	1.52	4.65	1.51	-7.36**	151
Willingness to participate	4.68	1.30	5.20	1.14	-5.19**	151
Satisfaction	4.01	1.50	5.35	1.27	-10.30**	152
Collaboration	4.54	1.37	5.46	1.23	-10.76**	150
Relevance	4.41	1.30	5.65	1.06	-8.15**	152

Note: *p ≤ .05. **p < 01

DISCUSSION

This study set out to investigate whether a technologically-mediated participatory and collaborative design approach was a feasible model for the professional development of a cohort of 26 in-service teachers. Findings indicated that the use of technological mediation and the combination of (a) tools that can support teachers' asynchronous and synchronous communication, (b) authoring tools to support the design process, and (c) human scaffolding -CPD providers- of teachers' discussions and enactment processes could contribute to the development of a better understanding of the inquiry process and could lead to motivating learning environments for students.

Taking into account reports in the literature suggesting that top-down reform efforts are doomed to fail if they do not cater to local needs (e.g. Mamlok-Naaman, Hofstein, & Penick, 2007), this work provides insights into a mechanism for including cohorts of teachers in efforts to develop and to implement innovative curricula. Our findings indicate that this approach has the potential to increase teachers' ownership, can strengthen teachers' pedagogical content knowledge (Blonder, Mamlok-Naaman, Kipnis, & Hofstein 2008) and can help teachers develop a more nuanced understanding of the inquiry process. More specifically, the PROFILES teachers indicated that the participatory design approach gave them the opportunity to collaborate productively with their colleagues, while it also helped them to enrich their knowledge by learning about new pedagogical approaches and technologies. At the same time, the teachers highlighted that the modules developed were more tailored to their students' needs and emphasized that this process could support more effective teaching, due to better understanding of the design rationale of the modules developed. These findings are aligned with previous studies which concluded that participatory design processes can promote the social and the cognitive development of the science teachers, while at the same time can yield learning environments which are more relevant to students' and teachers' needs and expectations (e.g. Chin Jr., 2004). Indeed, the learning environment designed by the nine chemistry teachers in our study addressed students' needs, school and curriculum limitations, and the teachers' own teaching skills and abilities.

The findings of the study support the claim that the technology-supported participatory design process allow teachers to develop an inquiry-based module, which is much more aligned to their students' needs and teaching realities, resulting in a product of high usability that, according to Damodaran (1996), can elicit teachers' and students' acceptance. In agreement with previous studies (e.g. Blonder, Mamlok-Naaman, Kipnis, & Hofstein 2008), our findings indicate that teachers develop a sense of ownership towards the learning environment, since the learning environment is not an extraneous imposition from above, namely an innovation imposed by the administrators or policy makers of the educational system. The developing sense of ownership is discussed in the literature as crucial in ensuring the successful implementations of reform efforts (e.g. Pintó, Couso, & Gutierrez, 2005). Without a sense of teachers' ownership toward the inquiry-based teaching and the PROFILES modules implemented, instruction is not meaningful and thus, students' motivation suffers (e.g. Rannikmäe, Teppo, & Holbrook, 2010). Considering that the inquiry-based module developed and implemented by the chemistry teachers has a positive impact on students' motivation to learn science, our findings provide empirical documentation of the participatory design approach as a valid method in developing teachers' sense of ownership of inquiry-based learning environments.

At the same time, several factors negatively affected teachers' participation and contribution to the participatory design process; future research should focus on the mitigation of these factors, aiming to increase the immediacy of the process as well as to ensure equal contribution from all the participants. Supporting teachers in adopting novel approaches to teaching is a challenging task; selecting appropriate tools, in addition to other types of support, is one step towards achieving our goal. As our experience shows, there is a lot of facilitating work that needs to take place in order to ignite and sustain productive communication and professional growth. However, focusing on the teachers' willingness to participate in the development and subsequent implementation of the teaching modules instead of following a top-down approach, we argue that the participatory design approach is a potent way for developing motivating learning environments that capture students' interest and support teachers' continuous professional development.

CONCLUSIONS

The present study set out to investigate technology-supported participatory design as an approach to support science teachers' professional development. For this reason, we pursued three questions. In our first research question we investigated the teachers' perceptions of the affordances and trade-offs of the technology-supported participatory design approach. Our findings indicate that teachers recognized challenges and benefits in this participatory design approach but they indicated that being involved in the design and adaptation process itself was much more effective in familiarizing them with the PROFILES approach and helping them meet the needs of their students. Furthermore, the negative issues identified by the teachers related mostly to the time required to engage in the process of design and coordination of the PROFILES modules, as well as to personal issues. Such issues are common in many professional development programs (Loucks-Horsley, Stiles, Mundry, Love, 2009).

Our second research question investigated the teachers' design process; findings indicated that the PROFILES 3-stage pedagogical framework helped focus the teachers' discussions on themes that are important for developing modules that adhere to the education through science approach (Holbrook & Ranninkmae, 2007). Six themes and several sub-themes were identified; while one of the themes was, naturally, related to issues about the integration of technology in the PROFILES modules, the other themes were all related to the PROFILES 3-stage module. The sub-themes indicated that teachers' design process problematized aspects such as, for example, how to design an authentic and motivating socio-scientific scenario, the type of inquiry activities that would help students reach an evidence-based decision, the level of guidance students would require to successfully engage in inquiry, etc. These findings strengthen our conclusion that the context of the professional development and the 3-stage PROFILES approach supported the teachers' professional development.

Finally, the third research question we asked related to the impact of the teachers' designs on student motivation to engage in science learning. Results indicated that the PROFILES modules designed by these teacher teams were successful in motivating students as compared to other traditional approaches to learning science. Taken together, these findings are significant as they support the participatory design approach for developing teachers' sense of ownership towards the education through science PROFILES approach as well as in developing learning environments that motivate student learning.

Acknowledgments

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 266589. We thank our colleague Andri Ioannou for her support in the initial phases of the PROFILES continuous professional development program and all the participating teachers for a mutually beneficial learning experience.

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