Teacher Belief and Change about Integrating Nanoscale Science and Technology into a Secondary Science Curriculum

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Abstract

The purpose of this study was to understand science teachers' perceptions on integrating nanoscale science and technology (NST) ideas into their classrooms. Specifically, we studied barriers that might inhibit them from incorporating nanoscale science and technology ideas into their instruction. Fifteen teachers participated in a workshop, which provided them with instructional materials, resources, and activities on emerging nanoscience topics that could be incorporated into their classes. Surveys were administrated at the beginning and at the end of the workshop, and follow-up interviews were conducted three months later. Our findings detail intrinsic and extrinsic barriers in teachers' perceptions to implementation of nanoscale science and technology ideas into instruction. Teachers' perceptions shifted over time, likely as a result of participating in the workshop, and in the long term. We conclude with discussing four main themes that emerged from the data: teachers' knowledge and capability to teach NST; relevance of NST in secondary science; time constraints in the curriculum and to prepare lessons on NST; and teaching materials and resources on NST.

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Introduction

Nanoscale science and technology (NST) is an increasingly new field of research and development that involves the exploration, imaging, measuring, modeling, and manipulation of matter at the length scale of 1-100 nanometers (NNI, 2010). It has a great impact on our lives as it is developing in various fields such as medical equipment, cosmetics, and electrical tools. Smartphones, nanomedicines, and nanomaterials, are just a few examples of the existence of NST devices in our lives. Besides, the need of the worldwide workforce in the area of nanoscale science and engineering is increasing rapidly (Roco, 2003). Therefore, there is a need for training nanotechnology-skilled workers on one hand, and citizens who are nanotechnology consumers that are able to consider its risks and benefits on the other hand (Abicht, Freikamp and Schumann, 2006; Sasson, Steinger, Dori and Peskin, 2007; Toumey and Baird, 2008).

The relevance of NST to our lives points to the relevance of NST to the science curriculum. Recently, the physical sciences part of the National Research Council (2011) document emphasized the need for including ideas of manipulation and fabrication at the nanoscale that 'allows the design of new types of materials with particular desired functionality' (Core idea PS1.A).

In Europe and the USA, higher education institutions are rising to the challenge and are offering courses, degrees, seminars, and training sessions in nanoscale science and technology (NST) for undergraduate and graduate science and engineering students (Glenk, 2003; Kulik and Fidelus, 2007; Malsch, 2008). The number of these programs is increasing rapidly in universities and colleges, but programs for K-12 are still in their initial stages. Initial efforts to develop educational programs on NST for K-12 are being done worldwide. Several computer-based materials and simulations for K-12 are available on the World Wide Web, such as *nanoZone*, *NanoKids*, and *NanoLand*. Museums also take part in NST education and develop exhibitions which deal with NST. The Nanoscale Informal Science Education (NISE) network provides activities and encourages interactions between informal education institutions.

In the formal education system, during recent years, programs and professional development workshops were developed in order to encourage teachers to incorporate nanoscience into their instruction. For instance, Daly and Bryan (2007, 2009) and also Hagedorn, Hunt, Suskavcevic, Manciu, and Manciu (2008) implemented a series of two-week professional development workshops, led by the National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT). Another effort described by Tomasik, Jin, Hamers and Moore (2009) outlines how they designed an online nanoscience course for middle- and high-school teachers. Specific activities on NST topics that can be integrated into science lessons were developed by Gail Jones, Falvo, Taylor and Broadwell (2007) and by Planinšič and Kovač (2008). Stevens, Sutherland and Krajcik (2009) equipped teachers with the big ideas of nanoscience and with ways to relate these ideas to the 7-12 curricula. All these activities, programs, and workshops focus on incorporating concepts of nanoscale phenomena into middle- and high-school curricula by providing teachers instructional materials that can be used directly in their classrooms.

Yet, NST does not explicitly exist in K-12 curricula and standards, and therefore, teachers' opportunities to embed these ideas are limited and depend mainly on each individual teacher's content knowledge and motivation. In such cases, several impediments might inhibit teachers from covering the new concepts in their classrooms. This paper reports science teachers' perceptions on barriers that might prevent the incorporation of NST ideas into the curriculum, followed by the change of those perceptions as a result of participating in a NST workshop.

Theoretical framework

Teachers' barriers to integrating new ideas into classrooms

Teachers face barriers when they wish to renew their teaching by integrating new concepts, pedagogy or technology into their classrooms. The science education literature discusses barriers that must be overcome for teachers to acquire and teach new ideas, such as adopting an inquiry approach (Anderson, 2002; Supovitz and Turner, 2000; Welch, Klopfer, Aikenhead, and Robinson, 1981), integrating Nature of Science ideas (Abd-El-Khalick, Bell and Ledermen, 1998), and incorporating new technologies into classrooms (Ertmer, 1999; Rogers, 2000). Although the contexts mentioned above have many differences, scholars identified similar types of barriers that might prevent teachers from teaching the new ideas.

Anderson (1996, 2002) defined three dimensions of barriers teachers have to face while implementing change efforts: technical, political and cultural. The technical dimension includes teachers' content knowledge and pedagogical content knowledge, textbooks, assessment, difficulties in group work, and in teachers' and students' roles. The political dimension is composed of parental resistance, conflicts among teachers, and lack of resources. The cultural dimension refers to teacher's beliefs about assessment, knowledge, and skills students need for the new instruction. Ertmer (1999) classified teachers' barriers as being first-order or second-order. First-order barriers are extrinsic to the teachers, and refer to resources, time to plan instruction, and administrative support. The second-order barriers are intrinsic to the teachers and include beliefs about teaching, classroom management, and willingness to change.

Although Anderson (1996, 2002) and Ertmer (1999) defined different dimensions or classes of barriers, they both described almost the same components. Based on these components, we defined two dimensions of teachers' barriers: *intrinsic* and *extrinsic*. Intrinsic barriers include impediments that prevent teachers from teaching the new ideas because of reasons which are internal to the teacher and do not depend on the context of teaching, such as self-efficacy, lack of knowledge, and beliefs regarding teaching in general, and regarding teaching the specific new ideas in particular. Teachers may have insufficient knowledge and lack of confidence in teaching the new concepts, no experience with the new pedagogy, and a low estimation of their ability to change their way of teaching. Extrinsic barriers include impediments that prevent teachers from teaching the new ideas because of reasons which are external to the teacher and highly depend on the context of teaching, such as textbooks, resources, standards, time constraints, parental resistance and lack of administrative support.

Barriers in teaching nanoscale science and technology in school

Different barriers, challenges, and difficulties stand in the way of incorporating NST ideas into school science curricula. First, the concepts and skills which are required for learning concepts and ideas that are rooted in nanoscale might be too difficult to comprehend for K-12 students who do not yet have sufficiently advanced science and mathematics background (Goodhew, 2006; His, Sabelli, Krajcik, Tinker and Ellenbogen, 2006).

Second, nanoscience crosses disciplines, combining the classical physics, chemistry, and biology. Moreover, scholars emphasize the importance of discussing nanotechnology from additional perspectives such as health, social, and economic in order to introduce students to the ramifications of that field (Planinšič and Kovač, 2008). School science curricula are largely disciplinary, and therefore, do not fit the interdisciplinary nature of nanoscience (Gyalog, 2007; His, Sabelli, Krajcik, Tinker and Ellenbogen, 2006; Planinšič and Kovač, 2008; Roco, 2003, 2004).

Finally, teachers' pre-service programs in the past did not include nanoscience topics, and therefore, in-service teachers who trained years ago, have lack of knowledge about nanoscience. Accordingly, they hesitate to deal with and teach NST topics. Healy (2009) indicated, that in a recent National Science Teachers Association (NSTA) annual meeting, teachers have shown having little to no knowledge about nanotechnology. They did not see how nanoscience topics could be included in their science teaching and they addressed the need for professional workshops and on-line support to direct them how to include nanoscale science and engineering in their teaching.

The study we present here deals with teachers' beliefs regarding barriers they have in incorporating NST in their classrooms following an exposure to NST topics. The significance of this research is by revealing these beliefs, as well as looking at their change over time following a short intervention described here.

Purpose of the study

The goal of this study was to reveal teachers' perceptions on the barriers that might inhibit them from teaching NST and the change of those perceptions as a result of participating in a one-day NST workshop. The research questions that guided the study were:

1. What are teachers' perceptions on barriers in integrating nanoscale science and technology ideas into their classrooms?

2. How do those perceptions change over time as a result of participating in a nanoscale science and technology workshop?

Methodology

The study followed teachers who participated in a one-day NST workshop that was held at a College of Engineering at a large midwestern university. That workshop was led by microelectronic engineers, who hold Ph.D.s in electrical engineering, work in a microelectronics laboratory in the university, and are members of the NSF National Nanotechnology Infrastructure Network (NNIN). The goals of the workshop, as stated by its organizer, were to expose teachers to educational programs that deal with nanoscience, and to provide teachers with instructional materials, resources and activities on NST that could be incorporated into lessons.

During the workshop, the teachers were exposed to basic concepts of nanoscience and to examples of the manufacturing process of some nanotechnology devices. They listened to an introductory talk about NST concepts and about the educational activities of the NNIN. They were exposed to several online resources, such as: Nanooze, Nanosense, and NanoEd. They visited 'clean rooms' in which they were exposed to micro and nanoscale fabrication techniques, and fabricated a demo device that presents the layers of a microelectronics chip. Teachers took part in hands-on activities for students that can be implemented in the classroom, such as mixing 'magic sand' with water, dirtying nanopants, and building a model of a Carbon 60 ball. They received instructional materials and educational resources on NST that included a teacher's guide to the National Science Education Standards that refer to NST, and background about nanotechnology. In addition, they received student worksheets for the hands-on activities that can be used in classrooms.

Fifteen science teachers, eight males and seven females, from mid-western towns and cities, participated voluntarily in the NST workshop. Eleven teachers had M.Sc. or M.A. degrees, and four had a B.Sc. degree. All fifteen participants were experienced teachers, with two of them having less than five years of teaching experience, two having taught between five and ten years, and all of the remaining eleven teachers having more than ten years of teaching experience. Table 1 presents the school grade levels and subjects taught by the fifteen participants.

Table 1. Nanoscience workshop participants

Subject of teaching	Middle school	High school	College
Chemistry		3	
Physics		2	
Biology		1	
Integrated Physics and Chemistry	1	1	
General Science	3		
Other: computer science, CAD, manufacturing	1		3

Data Collection

In order to reveal teachers' perceptions on barriers in integrating NST ideas into classrooms, data was collected at three times: before the workshop, immediately after the workshop, and three months later.

Pre-post surveys. The open-ended item surveys were developed based on Daly, Hutchinson and Bryan (2007) and Daly (personal communication, September 23, 2008), who examined teachers' perceptions and knowledge during a professional development workshop on NST topics. The aim of the survey was to gather background information about the teachers, about their perceptions on their capability to integrate NST ideas into their classroom, on the suitability of NST concepts to the school science curricula, and on causes that might inhibit covering the concepts in classrooms (detailed in the Appendix). For example: 'Do you have some understanding of what nanoscience entails? Please indicate.' or 'Do nanoscience concepts fit into your school's science curricula? Please elaborate.'

The surveys were administered before the workshop and at the end of the day. Four teachers, who left the workshop early, did not complete the post-survey. Therefore, the comparison data does not refer to those teachers. During the workshop, the first author observed the talks, joined the teachers for the hands-on activities, and took field notes.

Three-month follow-up interview. Three months after the workshop, interviews with each individual teacher were conducted. This was done to examine whether and how teachers implemented the materials from the workshop in their lessons and to follow the change in their perceptions on integrating NST ideas into classrooms. For example: 'Did you incorporate nanoscience concepts in your current curricula?' If yes: 'What concepts and in what topic? What can you say about that experience? Will you do it again next year?' If no: 'Why? Do nanoscience concepts fit into your school's science curricula, and into what topic?'

Only eight out of the eleven teachers who filled the post-survey responded positively to requests to be interviewed. Five teachers were interviewed by phone, while two other teachers were interviewed at their school. Both phone and face-to-face interviews were recorded and transcribed. One of the teachers preferred to write his responses to the interview protocol instead of being interviewed.

Data Analysis

Both pre-post surveys and three-month follow-up interviews were analyzed according to the frequency of intrinsic and extrinsic barriers that emerged from the data. The intrinsic barriers include all teachers' segments that related to impediments that prevent teachers from teaching NST ideas because of reasons which are internal to the teacher, and do not depend on the context of teaching. This category includes two sub-categories: (a) content knowledge about NST, and (b) capability to explain NST concepts.

The extrinsic barriers include all teachers' statements that related to impediments that prevent teachers from teaching NST ideas because of reasons which are external to the teacher, and depend highly on the context of teaching. This category includes eight subcategories: (a) teaching materials and resources; (b) time to prepare instructional materials and lessons; (c) time in the curriculum that enables adding new ideas; (d) administrative support in the school and at the district level; (e) suitability of NST ideas to state and national standards; (f) suitability of NST ideas to the school science curricula; (g) suitability of NST concepts to the students' age group; and (h) suitability of NST concepts to students' background in science and prior knowledge. The analysis process was conducted by two researchers in order to establish an acceptable level of inter judgmental reliability. An inter-rater reliability of 1.0 was achieved for the surveys and 0.95 for the interviews, and all rating inconsistencies were discussed and resolved between the researchers.

Presenting the data, we used a radar graph, a visual tool that presents the change in teachers' beliefs as a result of participating in a professional development workshop (Fallik, Eylon and Rosenfeld, 2008). We used that tool to present the frequency of different aspects of teachers' perceptions on intrinsic and extrinsic barriers on integrating NST into classrooms, and any changes in those frequencies seen immediately after the workshop, and three months later.

Findings

Pre-post survey

Teachers mentioned their perceptions on barriers, intrinsic and extrinsic, that might prevent them from including NST topics in their teaching. Figure 1 presents the barriers that the 11 teachers mentioned in their pre- and post-surveys, before participating in the workshop and immediately after (the analysis was done using Microsoft Excel Radar graph). For example, at the pre-survey nine teachers indicated having lack of knowledge, while at the post-survey only four teachers mentioned that barrier.

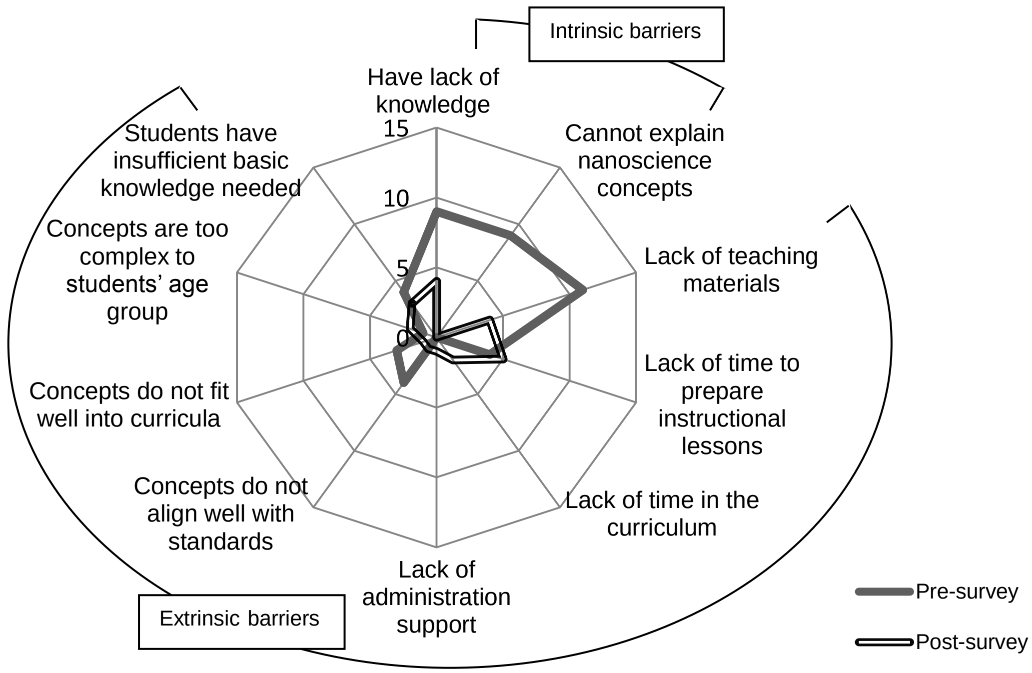

Figure 1. Pre- and post-workshop teachers' perceptions on barriers of integrating NST ideas into classrooms (N=11)

To interpret the graph, the shape of the graph represents the 'scope of barriers.' The graph in Figure 1 shows that the 'scope of barriers' decreased as a result of the workshop, since the area inside the shape diminished between the pre- to the post-workshop surveys. The diminishing in area indicates that teachers perceived fewer barriers in general in the post-survey as in the pre-survey.

The main change was in the intrinsic barriers: lack of knowledge, and the capability to explain nanoscience concepts. Teachers had more confidence in teaching NST immediately after the workshop than before it started, and therefore perceived these barriers as less dominant after the workshop. None of the teachers mentioned that they could not explain nanoscience concepts after the workshop, although most of the teachers considered this issue as a barrier before the workshop. Their perceptions regarding the lack of instructional materials also changed. This issue was the most important barrier in the pre-survey, however, because teachers received teaching materials and resources during the workshop, fewer teachers considered this issue as a barrier in the post-survey. Lack of time to prepare instructional materials was a minor concern before the workshop, but after the workshop it was the main barrier perceived. On the contrary, time in the curriculum and administration support remained minor even after the workshop. In addition, teachers did not consider the alignment of NST topics with standards and suitability to the curriculum as important barriers. Likewise, they did not perceive NST concepts to be difficult for their students' age group and thought that their students might have the background necessary for understanding NST.

To summarize, the intrinsic barriers decreased dramatically immediately after the workshop, as teachers gained confidence in teaching NST. Similarly, teachers believe that NST topics can be integrated in the curriculum, because they align to the standards, the existing curriculum, and the students' age group. However, time to prepare instructional materials was not mentioned at all in the pre-survey, but became the main barrier in the post-survey.

Longitudinal survey: Three months later

Three months after the workshop, some differences were found between the pre- and post-surveys and the three-month follow-up interviews. Figure 2 presents the main barriers that the eight interviewed teachers perceived as potentially inhibiting them from teaching NST topics, over the three data collection periods. The two barriers ‘Nanoscience concepts are too complex to teach to my students’ age group’ and ‘Lack of administration support’ are not presented here, as none of the eight interviewed teachers indicated them in neither the pre-surveys, post-surveys nor the interview.

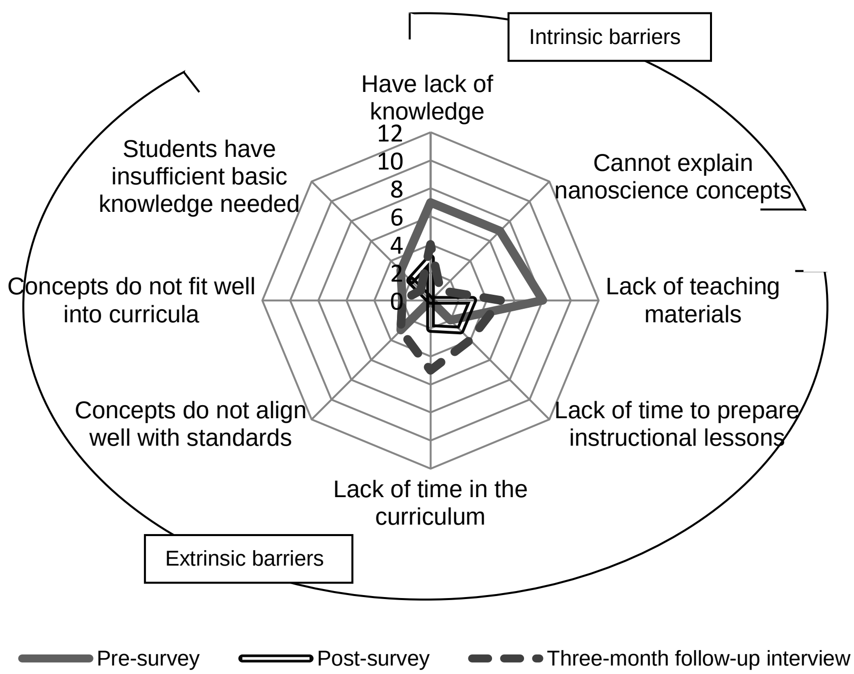

Figure 2. Short- and long-term teachers’ perceptions on barriers of integrating NST ideas into classrooms (N=8)

In general, the ‘scope of barriers’ changed during the three time points. The overall barriers decreased from pre- to post-surveys and increased again in the long term. The shape of the graph, which represents the dominant barriers perceived by teachers, has also changed at the three time points. That means that, in general, the influence of the workshop was more dominant immediately at the end of it, compared to three months later. The positive beliefs decreased over time, while teachers had to face constraints in the classroom. For instance, lack of time in the curriculum, which was not perceived as a barrier at all before the workshop, became dominant in the long term.

In general, teachers' reference to time issues was the main change from pre-survey to the long term. Teachers mentioned both time in the curriculum and time to prepare instructional materials as a barrier that might prevent them from teaching NST.

On the contrary, teachers’ perceptions regarding their capability to explain NST concepts was considered a dominant barrier before the workshop, but was almost negligible after the workshop as well as three months later. Teachers' concerns regarding the relevance of NST to secondary school was still limited, but in the long term, more teachers indicated concerns regarding how NST aligns with standards.

To summarize the longitudinal survey findings, the scope of barriers changed over time, and shifted from intrinsic barriers to extrinsic ones. As a result of the workshop, teachers had more confidence in teaching NST, even in the long term. They also think NST can fit the curriculum and their students' knowledge, but mention time barriers and lack of teaching materials that might prevent them from teaching NST. The next section qualitatively discusses teachers’ perceptions on intrinsic and extrinsic barriers in integrating NST ideas into the curriculum and the shift of those perceptions in the short and long term.

Intrinsic barriers: Teachers’ knowledge about and capability to teach NST

At the end of the workshop, all of the teachers (N=11) indicated they had a greater understanding of what NST entails and could explain NST concepts to their students, while only two teachers showed confidence in explaining those ideas before the workshop (as shown in Figure 1). For example, one of the teachers wrote: ‘I feel like I know better what defines it but also how it can be used in presents days’ (James [pseudonym]/post). They wrote about definitions that were discussed in the workshop, and about their understanding of the process of fabrication, which was presented in the ‘clean rooms’ and the hands-on activities. One of the teachers detailed how she will use the resources from the workshop: ‘First, I'll use the [name of resource provided after peer review], since that's how I generally teach. Then, I'll supplement with the other materials you provided, including the magazines’ (Alice/post).

Three months after the workshop, some teachers indicated lack of knowledge as a barrier to implementing NST into their classrooms but also mentioned the contribution of the workshop in overcoming that barrier. Kathleen said that she needs to put some effort into learning those concepts, but ‘I’m not fearful of it.’ Maureen explicitly connected her confidence to the workshop: ‘I think that [lack of knowledge] is part of it [difficulties of teaching NST]. I think, going to the workshop and learning about it is extremely important.’ The background with which teachers were equipped during the workshop was not only knowledge about concepts and processes, but also where and how to get more information and instructional tools. For example, Lisa described:

> ‘If I decide, you know, which I plan on doing that, this is something I want to do, I’ll dig around, I’ll ask around and get whatever I think I’m lacking. So, that’s [lack of knowledge] I don’t think a real, real problem, and they [at the workshop] gave us materials […]’ (Lisa/ interview)

Most teachers felt confident in their capability to teach NST topics compared with before the workshop, as well as in the long term. Their perceptions regarding their own capability to explain NST ideas changed as a result of the workshop, and stayed almost the same even three months later.

In summarizing the intrinsic barriers - teachers' knowledge about and capability to teach NST - they mostly decreased as a result of the workshop. The contribution of the workshop was in helping teachers gain confidence regarding their capability to teach NST. Although some of them mentioned in the long term that they have a lack of knowledge of NST, they would not hesitate to study NST, and know how to fill their gap in knowledge.

Extrinsic barriers

A. Relevance of NST in secondary science

Teachers were asked explicitly about how well NST topics fit into their school's science curriculum. As shown in Table 2, before the workshop, seven teachers responded 'yes', one teacher responded 'no', and three teachers were not sure, or not familiar enough with the concepts to decide.

Table 2. Teachers' perception of suitability of NST to the curriculum

Suitability of NST to the curriculum	Pre-survey	Post-survey
Yes	7	8
No	1	3
Do not know	3	0

At the end of the workshop those three teachers changed their perception regarding the suitability of NST to the curriculum: Maureen found connections between the hands-on experiences to inquiry-based curriculum she used in class, Kathleen came to the conclusion that 'the connections are very minimal,' and James indicated that teaching NST topics could be part of an extension or extra topics to cover.

Lisa, who responded negatively to the idea of suitability of NST ideas into the curriculum before the workshop, changed her mind and pointed out connections to STS topics she was teaching. However, Tom became more skeptical about how to fit NST into his classroom. Before the workshop, Tom wrote that those concepts fit his curriculum and should be fit into classes, especially physics. At the end of the workshop, he indicated the concepts did not fit, and therefore suggested a revision of the high school science curriculum.

In the long term, even teachers who did not integrate NST topics into their instruction indicated that these ideas can fit their curriculum. Lisa, for example, said:

> 'So, there are places to put it in the curriculum and integrate it in that course. For me, it's just a matter of time to sit down and say: okay, where does it fit and how can I get it to the kids.' (Lisa/interview)

On the contrary, Kathleen, who taught AP chemistry, mentioned that she doesn't have the opportunity to teach new ideas, whether they fit the curriculum or not: 'You don't have the choices that you would have in a regular curriculum.' She also mentioned that an over-loaded curriculum like AP chemistry does not allow any additions.

Regarding teachers' plans to incorporate NST in the instruction, nine teachers indicated their wish to incorporate NST topics, both in pre- and post-surveys. After the workshop, they could list the topics in which the NST will be incorporated. Some teachers were planning to connect NST to the structure of matter, for example: "I plan on teaching the structural behavior of atoms/molecules (basic). Then I will use the pictures I took, the PPT [slideshow], and my notes to explain the nanotechnology process" (Corry/post). Other teachers mentioned the importance of presenting cutting-edge topics to students, such as nanotechnology.

Only two teachers indicated in both the pre- and post-surveys, that they did not know if they would incorporate NST topics into their classrooms. One of the teachers wrote that it is possible, but she would have to see where it could fit into the curriculum. The other teacher mentioned that she was not planning to teach NST because of time constraints, as 'the curriculum is very full' (Kathleen/post). Actually, three months later, four out of the eight teachers who were interviewed already incorporated NST into their classrooms during the time between the workshop and the interviews. Teachers who did not incorporate NST mentioned that they might do so in the future, except Tom, who said that since those topics are not in the physical science curriculum, he will not teach them.

The four teachers who already integrated NST into their classrooms could report on the connections they found between NST and the curriculum and standards. Maureen, for example, connected concepts of size and scale to teaching about wavelengths. She used the magazines she received in the workshop when she thought about light and smell. Maureen emphasized the nanometer scale when she explained light wavelengths, and gave the students articles from the magazines to read that described the number of pixels that create a picture: 'They were really amazed at the amount of pixels they are going into a certain picture. Because, they told them about digital camera how many pixels are in' [sic].

Alice also talked about the nanometer scale when she taught the topics of molecules and atoms: 'When learning about the atom we spent time focusing on how really small its size is, we spent time, you know, focusing on the size.' She was planning to take her students for a fieldtrip to the Nano-camp at the university laboratory, and during the preparation for that, she would teach them again the structure of matter: 'when we will schedule this fieldtrip, and, and, um, then we can revisit some of the concepts… we focus again on a... the atomic level.'

In the three-month follow-up interviews, five teachers agreed that NST aligns well with Michigan science standards. They talked about content: 'Just atoms and molecules' (Corry/interview); related to skills: 'Conducting investigation, raising questions, finding answers, problem solving' (Maureen/interview); or described a general connection: 'There's a whole chunk in every single science set of standards that talks about science and technology…and society. So, they fit in. Is there a specific objective that says nanoscience in there? I don't think so' (Lisa/interview). Maureen pointed out that NST align well with standards, and said: 'if you want to find them align well somewhere, you could find that'. Not finding a connection to standards, in her opinion, is only an excuse for not covering the new topics.

On the other hand, Tom, Fred and Terry indicated that the NST topics are not included explicitly in standards. Tom even mentioned that unless they were, he would not find time to teach them. He told us: ‘Contact [the] state board of education to ask them to include nanoscience in the state standards, perhaps in place of some other less relevant topics’ (Tom/interview).

In summary, the extrinsic barriers that related to suitability of NST to students’ age group and to students’ background in science were not strong obstacles in teachers’ perceptions that might prevent most of them from teaching the new ideas.

B. Time constraints in the curriculum and to preparing lessons on NST

A different pattern emerged regarding extrinsic barriers related to time constraints. Before the workshop, time was not mentioned as an obstacle that might prevent teachers from covering NST topics. However, after the workshop, time was considered as a meaningful barrier, especially in the long term, as shown in Figure 2. Teachers argued that there was a lack of time both in the curriculum and for preparing lessons. Kathleen, for example, mentioned in the post-survey that she would probably not incorporate NST topics into her classrooms because of time constraints. Three months later, she shared with us her time constraints, and related them to pressure caused by her students' parents:

> ‘I would have to be smart of how to put it together, because there would be parents that said: ‘this is not in the AP test’, so if it’s before May (the AP test), ‘are you causing my poor child not to get a five?’, because that’s all […] to some of these kids.’ (Kathleen/interview)

Corry described the pressure caused by the lack of time as well:

> ‘You know, so, teachers, like when I taught science, I was harried to cover everything I was supposed to, and then, kind of add something else, that takes even two or three weeks, kind of kitschy from doing the other subjects. Because the kids have a test, that MEAP [Michigan Educational Assessment Program], and then the teachers are like under pressure: MEAP, MEAP, MEAP. You know what I mean?’ (Corry/interview)

Tom, Alice and Maureen joined them, saying that time is a meaningful constraint. As Tom said:

> ‘There are state mandates in the courses we teach which take up the bulk of our available time… So there is just no time at all in the course or any time for teachers to prepare lessons to teach this new content… but it is certainly very interesting!’ (Tom/interview)

C. Teaching materials and resources on NST

Another extrinsic barrier that was considered by teachers was the lack of teaching materials and resources. It was perceived as the main barrier in the pre-survey, and became again one of the most common barriers in the three-month follow-up interview along with time constraints (see Figure 2). In the interviews, Corry asked for more magazines which better match his middle-school students' level of knowledge. Lisa and Tom, who taught high-school students, asked for more materials that fit that age group, since the resources they received in the workshop were of lower or higher levels. Teachers seeking materials and resources became the main need of teachers in the long term.

In this section, we indicated three main teacher beliefs regarding the integration of NST in secondary school that changed over time: relevance of NST in secondary science; time constraints in the curriculum and to prepare lessons on NST; and teaching materials and resources on NST. In the next section we discuss the extrinsic and intrinsic barriers discussed in the previous section. We also suggest ways to help teachers overcome the barriers they have about integrating NST into the secondary science curriculum.

Discussion

In this initial, exploratory study we presented science teachers' perceptions on integrating nanoscale science and technology (NST) ideas into classrooms. Teachers' perceptions were categorized into two types of barriers that might inhibit implementing NST ideas into instruction: intrinsic and extrinsic. The intrinsic barriers related to obstacles that do not depend on the context of teaching, but only on the teachers' beliefs, knowledge, and self-efficacy. The extrinsic barriers related to obstacles that depend on the context of teaching and include students' difficulties, teaching materials, curriculum and standards, time constraints, and system support.

Initially, teachers perceived more intrinsic than extrinsic barriers, in general. But, after participating in a one-day NST workshop, they expressed more extrinsic than intrinsic barriers and perceived them as more dominant in preventing the incorporation of NST ideas into the instruction, even after three months. In the following sections we discuss the main themes of our findings: teachers' knowledge about and capability to teach NST; relevance of NST in secondary science; time constraints in the curriculum and to prepare lessons on NST; and teaching materials as resources on NST.

Intrinsic barriers: Teachers' knowledge about and capability to teach NST

Healy (2009) claimed that teachers reported having little to no knowledge about nanotechnology. The same phenomenon was found in our study, in which teachers reported having a lack of knowledge and no capability to teach NST ideas, before they participated in the NST workshop. But, teachers' perceptions regarding their knowledge and capability to teach NST shifted as a result of participating in the NST workshop. Teachers' self-efficacy is a fundamental issue in teacher education (Khourey-Bowers and Simonis, 2004; Ross, Hogaboam-Gray and Hannay, 2001; Watson, 2006), and a basic element in innovation in teaching. Research has shown that 'one-shot' programs failed at helping teachers achieve mastery of knowledge and skills (Coenders, Terlouw and Dijkstra, 2008; Loucks-Horsley, Hewson, Love and Stiles, 1998; Guskey, 2003; Richardson, 2003). Our findings show that regardless of knowledge and skills change, which were not examined in the study, teachers' perceptions of their own capability to teach NST topics changed positively, even three months after the one-day workshop. Although a 'one-shot' workshop is much less effective than a long-term one, it can serve as an initial step in teachers' learning (Watson, 2006), provided it is followed with other workshops or classroom experiences. It is also critical that these one-day workshops related to what teachers actually take away and implement in the classroom.

Extrinsic barrier A: Relevance of NST in secondary science

Teachers in our study claimed that NST topics could fit their curricula and their students' age group. This finding is counter to the claim that the concepts and skills which are required for learning NST may be too difficult to comprehend for middle- and high-school students, who do not yet have sufficiently advanced science and mathematics background (Goodhew, 2006). Although we did not document teachers' practices, their positive perception on the suitability to students' age group could be evidence that some NST topics can be adapted to middle-school and high-school levels. Teachers in our study reported incorporating NST content while teaching the structure of matter or ideas of size and scale. This finding is in line with Bowles' (2008) assertion, which suggests teachers incorporate NST ideas into instruction while teaching other topics which already exist in the curriculum and mentioned specifically measurement and size and scale ideas. Based on our findings and Bowles' assertion, we call for educators who wish to develop curriculum materials on NST for middle- and high-school students to focus their efforts on size and scale and the structure of matter issues. These two topics can be embedded in the existing curricula easily and fit the students' age group and scientific background.

Until now, NST is not mentioned in state standards and benchmarks (Stevens, Sutherland and Krajcik). Although Bowles (2008) listed National Science Education Standards (NSES) to which nanoscience ideas can be fitted, all attempts to incorporate NST into instruction were 'bottom up' efforts. A teacher could decide whether or not to participate in workshops and if and how to integrate NST into her classroom. Typically, only motivated teachers take that challenge to expose their students to the cutting-edge technology. Although most of the teachers in our study indicated a high connection between standards, their curricula, and NST, some of them claimed that until NST is explicitly placed in the standards they would not find time for teaching those topics.

Standards are a vehicle that can influence change in the local and the national levels (Powell and Anderson, 2002). Even though Anderson and Helms (2001) pointed out that no change can be driven from the top down, this direction is a necessary part of any change and reform. Hence, including NST explicitly in state and federal standards is a necessary step for incorporating these ideas into the curriculum.

Extrinsic barrier B: Time constraints in the curriculum and to prepare lessons on NST

Our findings pointed out that time constraints were the main barrier in teachers' perceptions. This is more than the other extrinsic barriers related to the context of teaching, especially after the workshop and in the long-term. Teachers stressed that time constraints, both in the scope of the curriculum and allotted for lesson preparation, prevented them from integrating NST into their classrooms, although those topics could fit into their curriculum. This finding is in line with a recent study done by Hutchinson, Bryan and Daly (2009), who found that time, was a factor that influenced teachers' choices of which NST topics to teach. Teachers in their study preferred to teach topics that did not consume much time, for both teaching and preparation. In addition, Johnson (2006) and Peers, Diezmann and Watters (2003) mentioned time as one of teachers' concerns about implementation of any new curriculum. Ignoring this barrier could cause any attempt for integrating NST topics into classrooms to be doomed to fail. Therefore, in order to integrate NST ideas, funds for schedules opened should be allocated for providing teachers time to find ways - where and how - to fit the new ideas into the curriculum. In order to give teachers the opportunity to improve and renew their teaching, we join Hawley and Valli (2000) who claim that teachers' learning time should be embedded into the school day. Flexible and creative scheduling is needed that will be dedicated for renewing topics and teaching materials on NST.

Extrinsic barrier C: Teaching materials and resources on NST

The need for instructional materials and resources on NST was a dominant barrier found within teachers' perceptions. Before the workshop, and in the long term, teachers asked for materials that fit their students' level and could be used in classrooms. High-quality research-based teaching materials are needed in the area of NST (Gail Jones, 2008). As suggested by educational researchers (Davis and Krajcik, 2005), new educative curriculum materials should be developed that serve as cognitive tools in order to help teachers add new ideas and make connections between new and old ideas. In making connections between new and old topics, teachers might need help in finding ways how to use new materials and where the new ideas fit (Borko, 2004; Darling-Hammond and McLaughlin, 1995; Ertmer, 1999; Fullan, 1993, 2001). The workshop in this study, as well as other instructional materials regarding NST, provided engaging activities in NST to teachers that could be implemented into classrooms (Gail Jones et al., 2007; Planinšič and Kovač, 2008). However, the question of how to integrate the new ideas and activities is still left to each teacher's discretion. Some teachers in this study mentioned the suitability of the new concepts to their curriculum, but had difficulties in finding ways to incorporate the concepts. Teachers' need for guidance in integrating new concepts has been addressed by national standards (AAAS, 1993); and hence, future NST workshops should help teachers in finding ways to connect the new ideas to their own context of curriculum and classroom.

Implications

The conclusions of this study provide a valuable knowledge about ways to help teachers perceive NST and integrate it in their classrooms. First, professional development needs to help teachers find ways to connect NST to the existing curricula. This can be done by specific guidance of making connections between new and old topics, and by showing exactly where and how in the curriculum the new concepts can be embedded.

In addition, the professional development needs to provide teachers instructional materials – workbooks and technology – and help teachers in finding ways how to use the new materials. Teachers need help in making adaptations to the curriculum to fit their students, and workshops can support teachers with ideas of how to make those adaptations.

As part of this study, teachers had the opportunity to talk about and reflect upon their barriers in implementing NST into their classroom. This opportunity is usually absent from teachers' everyday tasks, missions, and duties. Teachers' need for reflection upon their teaching, with facilitators or peers, is strongly suggested by scholars (Anderson and Mitchener, 1994; Blumenfeld, Krajcik, Marx and Soloway, 1994, 2005; Borko, 2004; Davis, 2003; Fullan, 1993; Powell and Anderson, 2002; Rennie, 2001; Roehring Kruse and Karen., 2007). Therefore, professional development must include follow-up communications and help teachers build their community of practice. This type of follow-up communication should not focus only on intrinsic barriers. Extrinsic barriers play a tremendously important role in teachers' everyday teaching (Anderson, 2002; Johnson, 2006; Peers et al., 2003), and hence, should be a part of the follow-up communication.

Limitations and further research

The strength of claims made by this study is limited by the short intervention of a one-day workshop and by the low number of participating teachers. The teachers were self-selected to participate in the workshop and may have had more motivation to learn about and teach NST.

The impact of nanotechnology on our everyday lives can no longer be ignored in K-12 science education, and the teachers are the agents for the preparation of students to be "nano-literate", i.e., students with relevant and sufficiently deep knowledge and skills for the new technology. A larger study over a longer, sustained time on teachers’ perception on and experience with teaching NST in schools might improve our insight of ways to help teachers overcome intrinsic and extrinsic barriers they have to deal with when they integrate NST ideas into their classrooms.

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Appendix A

Pre-post survey

1. Do you have some understanding of what nanoscience entails? Please indicate.

2. Do you plan to incorporate nanoscience concepts in your current curricula? Please explain why yes/no.

3. Can you explain nanoscience concepts to your students? If yes, please list them.

4. Do nanoscience concepts fit into your school's science curricula? Please elaborate.

5. Do you think that your students have shown interest in nanoscience topics? If yes, in which of them?

6. What impediments do you currently see that might inhibit you from covering nanoscience concepts in your classroom? (Mark all that apply.)

   (a) My lack of knowledge of nanoscience.

   (b) Lack of teaching materials and resources.

   (c) Lack of time to prepare instructional lessons or units.

   (d) Students have insufficient basic science knowledge needed for nanoscience concepts.

   (e) Nanoscience concepts are too complex to teach to my students' age group.

   (f) Nanoscience concepts do not align well with state science learning standards.

   (g) Nanoscience concepts do not fit well into existing curricula.

   (h) Lack of administration support.

   (i) Other: Please describe.

7. What supports can we offer to lessen the effects of the impediments you identified?

8. Which of the activities you have been exposed to can fit your students?

9. Are you going to come with your students to the cleanrooms? Why?

our students to the cleanrooms? Why?