CHEMISTRY TEACHERS INTRODUCE HIGH-SCHOOL STUDENTS TO ADVANCED TOPICS USING A POSTER EXHIBITION OF CONTEMPORARY ORGANIC CHEMISTRY

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ABSTRACT

The 21st century presents many challenges for chemistry educators. Chemistry as an evolving entity is not reflected in the existing high-school chemistry curriculum. The goal of the current study is to examine teachers' perceptions regarding introducing advanced topics in chemistry for high-school students by using a poster exhibition of contemporary organic chemistry. Four different groups of chemistry teachers participated in the study. The groups differ in their Content Knowledge (CK), and their experience in using the poster exhibition. The poster exhibition served as an effective means of support for teachers when high-school students were introduced to contemporary chemistry topics. CK was found to be an important component that positively influences teachers' self-efficacy for using the poster exhibition in their class. However, the teachers' CK was insufficient; the feelings of ownership and mastery experience are also important influential components that should be considered.

KEY WORDS

Chemistry education; Professional development; Modern chemistry; Poster exhibition; Teacher knowledge; Ownership; Teaching efficacy.

SISYPHUS
JOURNAL OF EDUCATION
VOLUME 2, ISSUE 2,
2014, PP. 48-73

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INTRODUCTION

Chemistry as an evolving entity is not reflected in the existing traditional high-school chemistry curriculum. The existing curriculum usually presents chemical concepts that were developed more than 100 years ago. However, different attempts have been made to integrate contemporary scientific content and methods into high-school chemistry: (1) Advanced laboratories invite classes of high-school students to use modern instrumentation (Blonder, Mamlok-Naaman & Hofstein, 2008); (2) Scientists come to schools and lecture about their research (Kapon, Ganiel & Eylon, 2009); (3) Science educators use adapted research literature (Yarden, Brill & Falk, 2001). These three methods, which are used for integrating contemporary chemistry (and science) into the existing curriculum, represent the role of scientists: They perform experiments in their laboratory, and communicate their results at scientific conferences (lectures) and in scientific journals (articles). However, scientists also use additional communication channels to present their research: scientific posters. The poster is a visual means that is used to briefly present scientific research at conferences (Stephen, 2011). The current study focuses on teachers' content knowledge, which supports them in using poster exhibitions of contemporary science in their classes.

The critical role of teachers in attaining the goal of quality education in the sciences is highlighted in the research literature on education. A recent international policy document written by Osborne and Dillon (2008) reflects a consensus on the importance of teachers:

> Good quality teachers with up-to-date knowledge and skills are the foundation of any system of formal science education. Systems to ensure the recruitment, retention, and continuous professional training of those individuals must be a policy priority in Europe (Osborne & Dillon, 2008, p. 25).

The notion of teachers' knowledge first came to prominence a quarter of a century ago (Shulman, 1987), and there has been a plethora of literature on what teachers know and do in order to carry out their work (Mulholland & Wallace, 2005). By acknowledging the central role of teachers in teaching, the teachers' use of knowledge places the practicing teacher at the heart of attempts to reform classrooms and improve student achievement. However, although there is much agreement about the importance of teachers' knowledge, there has also been numerous discussions, debates, and concerns regarding how teachers' knowledge is constructed, organized, and used (Kennedy, 2002; Kind, 2009; Munby, Russell & Martin, 2001). Many teachers completed their formal education a long time ago. As a result, their science knowledge and knowledge of important recent developments regarding science teaching (pedagogical knowledge and knowledge of new learning environments) are rather limited. This inhibits their ability to implement curricula that require contemporary scientific and pedagogical knowledge and to teach at an appropriate level and with the appropriate methodology (Van Driel, Verloop & De Vos, 1998).

Research findings on the effectiveness and professional development of teachers underscore the importance of teachers' knowledge and professional enthusiasm, as well as their pedagogical knowledge (Munby, Russell & Martin, 2001). What teachers know and how this knowledge distinguishes them from other knowers of particular subjects was defined by Shulman (1986, p. 9) as Pedagogical Content Knowledge (PCK), «which goes beyond knowledge of the subject matter… to the dimension of subject matter knowledge for teaching». Since then, PCK has come to be thought of as a special amalgam of subject matter knowledge and knowledge of pedagogy, long considered as separate, used in a type of professional understanding unique to teachers (Shulman, 1987).

In many respects, the work of Dewey (1902) foreshadowed the concept of PCK. According to Dewey, teachers' subject-matter knowledge differs from that of other individuals. The teachers were concerned not with subject matter for its own sake, as were other scholars, but rather, with subject matter as only one part of the whole spectrum of educational experiences that a learner undergoes. So important has the notion of PCK become, that in more recent times, researchers have called for subject matter knowledge to be taught to teachers as PCK in order for teachers to more readily transform their own understandings, so that they are suitable for teaching (Marks, 1990). Researchers have long debated the knowledge categories to be included as part of PCK and various definitions of it have evolved since Schulman's initial description (Van Driel et al., 1998). However, the notion of PCK has come to epitomize the computer or the knowledge-based metaphor of teachers' knowledge. In the two ensuing decades since Schulman's early work, the knowledge base movement has developed into a major effort to study the essential components comprising the knowledge base, and with the aim of determining how they affect it. Lists of such knowledge types, clustered in different ways and with different emphases, abound in the literature. They include content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, knowledge of educational aims, purposes and values, and moral dispositions. However, it is difficult to isolate specific elements of teachers' knowledge in research situations, because teachers have a holistic or integrated understanding of their work (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). The concept of PCK, for example, has fuzzy boundaries, which presents a challenge to those who attempt to add knowledge to its categories (Gess-Newsome, 1999). One of the difficulties associated with making more use of PCK lies in its elusive nature. According to a recent review by Kind (2009), pedagogical content knowledge is a 'hidden' concept, although it is a useful construct, and determining what it comprises and using this knowledge to support good practice in teacher education is not easy. Moreover, inconsistencies and disagreements persist concerning PCK, resulting in no overriding consensus about how this can best be used to describe effective science teaching. In Kuhn's (1962) terms, the PCK research field is still at the 'pre-science' stage; therefore, despite having been researched for over twenty years, it is not ready for wider dissemination (Kind, 2009).

OUR STUDY

Based on the above, a program for enhancing chemistry teachers' content knowledge as well as their pedagogical content knowledge was initiated at the Weizmann Institute of Science in Israel. The Rothschild-Weizmann Program for Excellence in Science Teaching was established for the academic and professional development of science and mathematics teachers in Israel. A two-year program for earning a M.Sc. degree in science teaching was established within the Feinberg Graduate School at the Weizmann Institute of Science.

The chemistry program consisted of three main topics: chemistry, science education and laboratory experience. The chemistry courses were specifically designed, and included three stages in which the teachers attended (1) the course lectures, (2) a 'follow-up' tutoring lesson, which was prepared especially for them by one of the staff scientists and was aimed at elaborating on the course lecture, and (3) a workshop coordinated by a researcher from the science teaching group, in order to apply the scientific knowledge to the educational field (Mamlok-Naaman, Blonder & Hofstein, 2010). The model reduced the teachers' anxieties resulting from taking academic scientific courses; they gained modern and advanced scientific content knowledge, and succeeded in applying it in their teaching. The chemistry courses were chosen to represent advanced and modern chemistry topics that are associated with the chemistry curriculum (e.g., medicinal chemistry, nanotechnology, materials, advanced organic chemistry, and chemistry of proteins). The science education courses included issues such as an introduction to chemistry education, inquiry-type teaching and learning, the diversity of assessment methods, etc. In addition to the courses, a laboratory experience was scheduled for the summer vacation. Every chemistry teacher spent two weeks in one of the laboratories, was involved in specific research, and wrote a report. The teachers were also asked to suggest how the research, in which they were involved, could be applied in their classes.

COURSE DESCRIPTION

In the current study we focused on the product of the third stage of the three-stage model: adapting the scientific knowledge to the field of education in the 'Organic reactions used in the total synthesis of natural products' course.

The three-stage model in this course included the following stages:

Stage 1 – Lecture: An advanced course in organic chemistry was given by Prof. Hassner in the form of conventional lectures. The course was open to M.Sc. students (the course was given three times at the Weizmann Institute of Science) whose work focuses on organic synthesis as well as to those chemistry teachers who were engaged in the M.Sc. program for chemistry teachers. The lectures included oral explanations that were taught together with organic chemistry equations that the lecturer wrote on the blackboard. A written exercise was given after every lesson. The evaluation of the course used a test that consisted of questions that were similar to those that were given in the exercises.

Stage 2 – Follow-up: a tutoring lesson was given after each lecture by an assistant staff scientist in the organic chemistry department of the Weizmann Institute of Science. This lesson was given separately to the teachers; the chemistry M.Sc. students had a different tutor.

Stage 3 – Adaptation to education: This session was conducted by the author, a researcher in the chemistry education group; she has a PhD in chemistry. The emphasis of this session was on applications in two dimensions: applying the advanced chemistry content to the field of education, and using the material to solve the exercises. Adaptation to education sessions was carried out as workshops in which the students (the chemistry teachers) usually worked in pairs and an educational guide aided their learning.

Assignment of stage 3 – The assignment was changed for the three cohorts that took the course. In the first cohort the teachers were asked to produce a poster that presents one concept or one synthesis that they learned in the course, which is appropriate for high-school students. As a result, seven posters were designed and printed. The second cohort was asked to design an activity for high-school students using the exhibition of the seven posters. The third cohort was asked to design an activity and to use the poster exhibition in their class. The posters in the poster exhibition are described in Table 1 (see next page).

POSTER PREPARATION AND POSTER COMPONENTS

The posters were part of the course assignments of the first cohort; each teacher had to choose one of the course topics and to produce a poster. These posters were

Poster title	Advanced subject matter	Basic concepts	Connections to everyday life
β-Lactam rings: the key for new antibiotics	Staudinger reaction	Synthesis of β-Lactam Penicillin structure	Antibiotics and its role in modern medicine
Carbocation equivalents and the secret of the orange smell	Acyl anion equivalents Asymmetric reactions	Chirality	Fragrances
The connection between retrosynthetic analysis and the way detectives solve crimes	Retrosynthetic analysis of a complicated example	Simple organic reactions	Crime Scene Investigation (CSI), reflective thinking
Mimicking nature using chemistry	Robinson annulation reaction	Chirality	Chemical ingredients used by man
Hydroboration in serving mankind	Hydroboration	Alcohols and their properties	Commercial medicines: Ventoline, anti-cancer treatment, antifungal cream, and more
What is the connection among organic chemistry, umpolung, and vitamin B12?	Acyl Anion Equivalent, the Umpolung principle	Carbonyl group, aldehydes, Krebs cycle	B12 Vitamin
Chemical dartboard	Directed aldols, Asymmetric reactions, protection groups	Functional group, enolate inion, nucleophilic addition	Mimicking nature by chemical synthesis

TABLE 1 — DESCRIPTION OF THE POSTER EXHIBITION ACCORDING TO ITS COMPONENTS

intended to help them teach the specific topic to their high-school students. The teachers were guided by the course tutor and by the educational guide regarding (1) choosing a topic, (2) finding a component that was connected to students' everyday life, and (3) integrating basic chemistry principles and concepts. The teachers (the first cohort only) presented their posters to those colleagues who participated in the program. Table 1 presents an analysis of the posters, showing different parts: the advanced subject matter that they chose, the basic concepts, and the connection to everyday life. The posters are shown in Figure 1.

RESEARCH QUESTIONS

Concerned with the lack of instructional materials for introducing cutting edge chemistry to high-school students, we were interested in determining whether this poster exhibition could be used by teachers other than those who developed it. Therefore, we investigated the following research question:

1. What knowledge do teachers need in order to be able to use the poster exhibition in their class?
2. What influences teachers' self-efficacy beliefs regarding their ability to use the poster exhibition that presents cutting-edge chemistry to high students?

The study will focus on different components of teachers' knowledge and their beliefs regarding their ability to present the poster exhibition to high-school students.

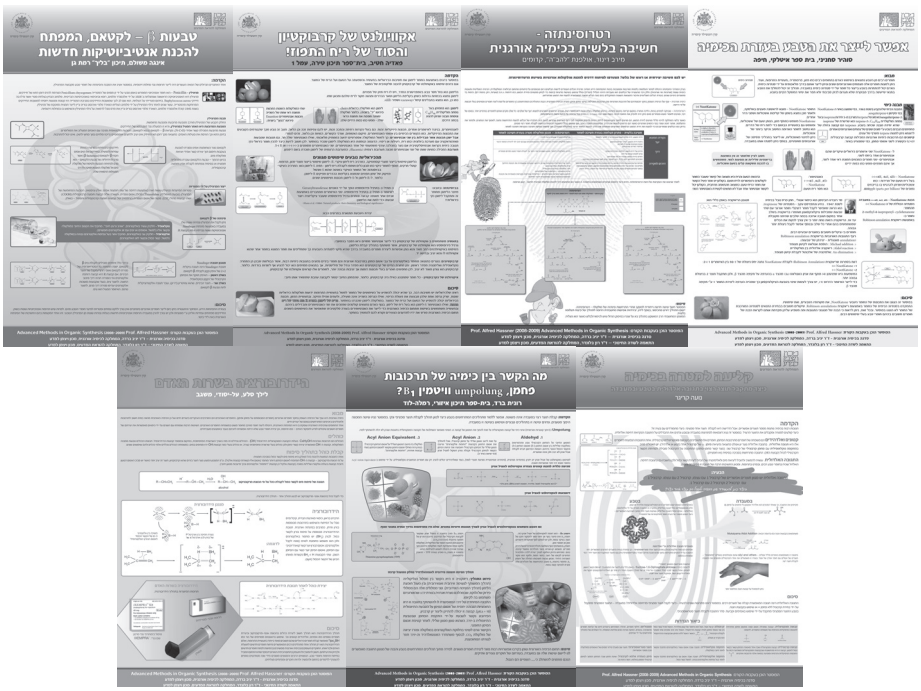

FIGURE 1 — THE SEVEN POSTERS IN THE POSTER EXHIBITION, PRESENTED IN THE SAME ORDER AS IN TABLE 1

METHODS

Participants: Four teacher groups participated in the study, as presented in Table 2. All the teachers in the study are experienced chemistry teachers (having more than 10 years of experience). The first three groups of teachers were students

in the Rothschild-Weizmann Program for Excellence in Science Teaching. The first cohort of teachers took the course and created the posters for the exhibition. The second cohort took the course and planned a student activity based on the poster exhibition. The third cohort took the course, planned a student activity, and performed it with their students. The last group includes leading chemistry teachers with second degree in chemistry. Teachers in this group did not participate in the course.

Teachers' group	Number of teachers	Took the advanced course	Created posters	Used the poster exhibition
(1) First cohort	7	+	+	-
(2) Second cohort	18	+	-	-
(3) Third cohort	11	+	-	+
(4) Leading teachers	17	-	-	-

TABLE 2 – CHARACTERIZATIONS OF THE DIFFERENT GROUPS OF TEACHERS

DATA COLLECTION AND ANALYSIS

Teacher Interview

Semi-structured interviews were conducted with the first cohort of teachers (group 1) at the end of the year. The interviews (60 min each) included two parts (Fontana & Frey, 1998). In the first part they were requested to freely describe how they apply their academic learning. The second part was semi-structured and guided the teachers to focus on and to express their opinion regarding the poster exhibition that they created. This part included the following questions:

- Do you plan to use the organic poster exhibition with your students? Please explain.
- What support do you need in order to use the exhibition in your class?
- In your opinion, what could the students gain from this kind of activity?

The interviews were audio-recorded, transcribed, and then analysed by the first author of this paper according to three main categories that emerged from the teachers' interviews: (1) their «feelings» towards the poster exhibition, (2) their perceptions regarding the content of the poster, and (3) their perceptions regarding using the exhibition in their classroom. The initial analysis was fol-

lowed by a secondary analysis conducted by an expert in science education research who re-read the interview transcription and commented on unclear category attribution. Then, the two researchers discussed the results until they reached a consensus. Interviews were analysed to determine the extent to which the teachers planned to implement the poster exhibition in their chemistry lessons. Finally, those factors that influenced their plans were identified.

Reflective Report

The assignment that was given to the teachers in cohorts 2 and 3 (groups 2 and 3) was to develop an activity in which they will implement the poster exhibition in the chemistry lessons. Group 2 was only requested to design the activity, whereas group 3 was requested to design an activity and to try it out in class. Teachers in the two groups were requested to describe the activities that were developed and to identify the following:

- The goals of the designed activity
- The pro and cons of using the poster exhibition with high-school students
- If they plan to use the poster exhibition and try your activity with your students next year

Teachers in group 3 that tried the activity in class as part of the course assignment were also asked to evaluate the success of their activity and to bring evidence to evaluate its success.

The three categories that emerged in the interviews were used to analyse the reflective reports.

Questionnaires

One of the teachers from the first cohort (the second author) designed an activity based on the poster exhibition for her students. A group of 17 leading chemistry teachers (group 4) were invited to participate and learn about this activity. This activity lasted two academic hours and included a guided reading of the posters, which were hung on the wall of the classroom. Then the leading teachers were requested to choose one of the posters and to deepen their understanding by following a student's work sheet. After the activity, the leading teachers were asked to fill out a questionnaire. In the questionnaire they were asked to describe their professional background and to answer the following questions:

- Did you find the poster exhibition activity to be interesting for you as a learner?
- Would you like to introduce this activity to your students? Please explain.
- What are the pitfalls of such an activity?
- What are the advantages of introducing high-school students to the poster exhibition?

In addition, the questionnaires were analysed according to the categories that emerged from the interviews.

Follow-up Short Interview

All the teachers from the four groups were interviewed one year after the third cohort completed the MSc program. The 30-minute short interviews were audio-recorded and transcribed. The goal of the follow-up interview was to learn whether the teachers actually used the poster exhibition in their class. The teachers were first asked to describe their feelings and what they have done in school since the last time that they have been at the Weizmann Institute of Science. Then they were asked if they made use of the poster exhibition as they had planned. These interviews were used for collecting technical information and therefore inter-rater validity was not required.

RESULTS

The results will be presented according to the different teacher groups in order to identify differences between teachers' knowledge and beliefs.

THE FIRST COHORT

The teachers in this group took the advanced organic course and designed the posters in the «adaptation to education» stage of the course.

(1) Teachers' «Feelings» Towards the Poster Exhibition

Most of the teachers in this group exhibited positive attitudes towards the poster. They created the posters, they are very familiar with them, and they even like them, as reflected from the following examples:

> One of the activities I plan to do with my students next year is to use the poster exhibition. I am familiar with the posters…
>
> I really like the posters – they are really good considering their content and their design.
>
> The colours of the posters make the exhibition very attractive and I love to see them all together creating a rainbow.
>
> I worked very hard to prepare my poster and the result is beautiful. Actually, I think that all the posters are great and very appealing for students.

A question regarding teachers' feelings or attitudes towards the poster was not asked directly in the interview. However, only two teachers did not reveal their feelings towards the posters, whereas the others described positive feelings. In addition, the teachers expressed their sense of ownership regarding their own poster and even regarding the entire poster exhibition.

(2) Teachers' Perceptions Regarding the Content of the Poster

The teachers described different components of the posters' content. They discussed the advanced organic content that was derived from the advanced course; they referred to the connection to students' lives and also discussed the pictures in the posters, as shown in the following examples:

> They [the posters] give the students access to cutting-edge science that are outside the chemistry curriculum and connect this advanced knowledge to their everyday life.
>
> I'm not afraid of the high level of the posters. On the contrary, students will learn some of the content. They will know – parts are too high for me – I need to learn more chemistry in order to understand them all.
>
> We had chosen photos of familiar objects (like the grapefruit) to explain chemistry concepts like enantiomers. We integrated examples from students' everyday life to connect them to the posters.
>
> Although the advanced organic-chemistry concepts that are presented in the

posters are very complex, I understand them well and therefore will be able to mention them to my students.

(3) Teachers' Perceptions Regarding Use of the Exhibition in their Classroom

The teachers were directly asked if they plan to use the poster exhibition in their class, and therefore all of them referred to this aspect:

> Next year I will use the poster exhibition. I really like to do the activity with them. I will just need to receive them and I'll do the activity.

> There is no doubt about that – I am going to use the poster with my students.

> One of the activities I plan to do with my students next year is to use the poster exhibition. I know the posters (…) The poster exhibition will introduce the students to the methodology of using posters for scientific communication whereby scientific knowledge is succinctly presented.

> I plan to use them when I'll teach functional groups because their content is connected to this chemistry content. They give the students access to cutting-edge science that is outside the chemistry curriculum and it links this advanced knowledge to their everyday life.

> I really like the posters – they are really good, considering their content and their design. I plan to use them when I'll teach functional groups because their content is connected to this chemistry content.

Only one teacher explained why she did not plan to use the posters with her class, as indicated in Table 3:

> I am not sure that I'll bring the poster exhibition to my class. My students are not so strong and usually I don't have time for enrichment.

Four teachers from the first cohort actually took the printed posters and used the exhibition in their class (Table 3). These four teachers stated in the follow-up interviews that they plan to use the poster exhibition again.

Teachers' group	Planning to use the poster exhibition	Actually used the poster exhibition	Stated that they will re-use the poster exhibition
First cohort	6/7	4/7	4/4
Second cohort	10/18	2/18	2/2
Third cohort	8/11	8/11	6/8
Leading teachers	5/17	0/17	-

TABLE 3 – IMPLEMENTATION OF THE POSTER EXHIBITION: PLANS AND ACTUAL USE

THE SECOND COHORT

Teachers from the second cohort took the advanced chemistry course and were also asked to design an activity for their students using the poster exhibition. Ten out of the 18 teachers in the group stated in the interview that they will use the exhibition but only two teachers actually did so, as presented in Table 2.

(1) Teachers' «Feelings» Towards the Poster Exhibition

The teacher found the exhibition to be very aesthetic but did not reveal any personal connection to the posters, as indicated from the following examples:

> I think that the posters are very beautiful.

> The design of the exhibition is appealing; together the posters create a rainbow of colours.

The teachers who chose to express their feelings regarding the posters described them as a group. They did not express any sense of ownership but rather, related to the way the poster exhibition is designed.

(2) Teachers' Perceptions Regarding the Content of the Poster

For most of the teachers the content of the poster seemed to be highly complex and very difficult for high-school students. They stated that even for them the advanced course was very difficult and they could not distinguish between the advanced course and the poster exhibition, as indicated from the following examples:

> It was very difficult for me to develop an activity for my students using the poster exhibition. The advanced course was not easy for me, although

> I received a high score, and I almost can't imagine an activity using these materials that will be suitable for high-school students.
>
> The posters, which expose the students to high-level chemistry, emphasize the organic synthesis and the chemical industry. The connection of the advanced content to students' everyday life is prominent.

About half of the teachers in this group saw mainly the advanced organic content, which is included in the posters. The other half related to the additional components of the posters (e.g., their connection to students' life, their connections to industry) and were less threated by the content of the posters.

(3) Teachers' Perceptions Regarding Use of the Exhibition in their Classroom

The teachers could be categorized into two groups, regarding their perceptions of the content of the poster. Those teachers who mainly noted the difficult content had difficulties in explaining why they would not be able to use the poster exhibition in their class. In contrast, those teachers who emphasized other components of the poster content described the advantages of using the poster with their students, as reflected in the following examples:

> Usually I don't have time for enrichments – and this activity will take a lot of time because the posters are so difficult to understand.
>
> It was very difficult for me to develop an activity for my students using the poster exhibition (…) I don't believe that the activity can work well with my students because the posters are too difficult.
>
> Bringing the poster exhibition to my class and doing the activity I prepared creates a unique opportunity to show my students the cutting edge of scientific research, and it shows them the connections to their life and to industry.
>
> There is no chance that will not do the activity. It is a great opportunity for me to share what I learned in my MSc degree and to introduce the advanced content in such a way that students will understand.

THE THIRD COHORT

Teachers from the third cohort that took the advanced chemistry course were asked to design an activity using the poster exhibition and to pilot the activity in their class. Ten out of the 11 teachers in the group used the exhibition (it was the course assignment for this group), and most of them stated that they planned to reuse the poster exhibition.

(1) Teachers' «Feelings» Towards the Poster Exhibition

After developing and piloting the students' activity in class, the teachers developed positive feelings and attitudes towards the posters, as was indicated in their reflective reports:

> The posters are so beautiful; actually I discovered this when I worked on my assignment and had to look carefully at the poster.

> I can't find any pitfalls in the posters – they are great. Each poster presents a different work in the cutting edge of organic chemistry and connects it to students' life and also shows the students that there is still what to discover.

However, three teachers in this group asked not to pilot their activity in class, since they taught middle-school students the same year and not high-school students for whom the posters were designed. These teachers received the same assignment like the first cohort of teachers, namely, to design a poster. This poster was designed but was never printed and therefore was not part of the poster exhibition. The third teacher received the assignment of the second cohort, namely, to design an activity for her students without piloting it in school. The two teachers had negative attitudes towards the posters. They felt the assignment was not relevant for them and was very demanding, as reflected from the report they submitted with the poster:

> I don't think that these posters can be really used in school. They are much too difficult and I don't think that young students will be connected to them, since even I can't learn from them.

(2) Teachers' Perceptions Regarding the Content of the Poster

The teachers could distinguish between the high level of the advanced course and the content of the posters. They highlighted the ways in which the posters aid high-school students to learn the difficult organic chemistry content:

> The organic chemistry course was the most difficult course for me – the poster gave me an opportunity to rebuild my confidence. I like organic chemistry after all.

> The posters are not so complex as the course; they expose the beauty of new developments in chemistry research.

> The poster exhibition shows the connection between real life and advanced organic chemistry – the posters are appealing for students and for me too.

(3) Teachers' Perceptions Regarding Using the Exhibition in their Classroom

The teachers in this group actually used the poster exhibition in their classes. Therefore, their perception regarding use of the posters is based on reflective evaluation of their activity. The three teachers who did not complete the assignment explained that the posters were too difficult for their students and that they lacked time to include in their teaching an activity that is outside the chemistry curriculum. Most of the teachers who used the posters in their class were very surprised by the success of the activity, as indicated from the following examples:

> The pedagogy is really student-centred; they could choose the poster they want to focus on and they don't have many opportunities like this in school.

> I was amazed by my students' reactions – they were so enthusiastic and cooperative. There is no doubt that that I'm going to do that again next year!

> My students really liked the posters. They read them carefully and asked me a lot of questions regarding them.

> I was sceptical, because I thought they are too difficult for them. But they [my students] were very interested in them. First, they looked at the exam-

ples that were connected to their life, and then they started to surf the internet to lean new concepts. I was very surprised.

LEADING TEACHERS

Teachers from this group did not take the advanced chemistry course; however, they all hold at least an MSc in Chemistry and therefore they had taken an advanced course in organic chemistry. They were exposed to the poster exhibition and a workshop for leading chemistry teachers. In the workshop they performed the activity that was designed by the second author (as learners) and were asked to fill out a questionnaire. Five out of the 17 teachers in the group thought that they will use the exhibition. They were not asked about their «feelings» towards the poster exhibition because this category emerged from analysing teachers' interviews only after they had completed the activity. Therefore, we do not have direct evidence regarding their feelings and of their sense of ownership regarding the posters.

(1) Teachers' Perceptions Regarding the Content of the Poster

The leading teachers indicated that they learned a lot from the activity. They learned new directions in organic synthesis, and found new connections to everyday life and industry.

> My knowledge regarding organic synthesis stopped ten years ago when I finished my MSc degree in chemistry. The poster exhibition provided me with the opportunity to learn new developments in the field.

> I know that chemistry is everywhere and I also tell that to my students, but I never realized that even organic chemistry is so connected to everyday life; for me it was always an area that stays in the laboratory.

> It was not easy for me to fully understand the advanced content – I need more time for that.

(2) Teachers' perceptions regarding use of the exhibition in their classroom

The teachers were asked whether they like to introduce this activity to their students and to describe the pitfalls and the advantages of such an activity.

Most of them referred to the advanced organic chemistry content, which would be too difficult for their students, as the main reason for not using the activity in class. The content knowledge of this group of teachers, who had not taken the advanced course, was lower than that of the teachers in the other groups.

> I liked the activity but it was not easy; I think that my students can't do that.
>
> This is too hard for high-school students.
>
> I don't have time for enrichments; I must prepare them for the external exams.

However, the leading teachers are very experienced teachers and were impressed by the pedagogy underlying the poster exhibition.

> The poster exhibition uses a pedagogy that put the student in the centre of the learning. The student will feel like he is at a scientific conference in which the researchers can choose which poster to read.
>
> I can imagine myself using the posters with my students in an activity that will summarize functional groups in organic chemistry. They don't have to fully understand all the details in the posters. They will the opportunity to see how organic chemistry in connected to everyday life.

DISCUSSION

The discussion is based on integrating the results from the different research tools consisting of (1) interviews with teachers, (2) a reflective report, (3) a questionnaire, and (4) follow-up short interviews conducted a year after the end of the course. The discussion will be presented according to each research question.

(1) *What knowledge do teachers need in order to be able to use the poster exhibition in their class?*

Only five teachers from the leading teachers' group wrote in the questionnaire that they planned to use the poster exhibition with their students. In contrast

to the teachers from the first three cohorts, who took the advanced organic course, the leading teachers indicated that their previous knowledge was not enough to completely understand the posters' content. Moreover, none of the leading teachers actually used the posters. This supports the notion that teachers' content knowledge is a necessary condition to introduce the poster exhibition activity to the class. When Shulman (1986) distinguished three kinds of knowledge that lie at the heart of the teaching profession, he started with subject knowledge content knowledge: «the amount and organization of knowledge per se in the mind of the teacher» (Shulman, 1986, p. 10). Shulman continued and emphasized that «The teacher needs not only [to] understand *that* something is so; the teacher must further understand *why* something is so» (Shulman, 1986, p. 9), namely, the content and its context. The leading teachers did not know the content of the poster exhibition and a fortiori they did not know the context of the advanced knowledge. It is therefore reasonable that lacking the relevant content knowledge, the teachers did not feel capable of using the poster exhibition in their class. There are many evidences that show the relationship between the teachers' subject knowledge and their attempts at implementing this knowledge in their lessons (e.g., Smith & Neale, 1989).

Ball, Hoover, and Geoffrey (2008) distinguished between «pure» content knowledge unique to the task of teaching and specialized content knowledge, which is distinct from the common content knowledge needed by teachers and non-teachers alike. Therefore, «pure» content knowledge is not enough. Not all the teachers who took the advanced course felt they could handle this activity with their students. Teachers' interviews and their reflective reports indicated that the third group who designed an activity for their students and piloted it in school was the group that adopted the activity at a higher percentage rate than the other groups, even after the course. A more careful look at the results shows that teachers from all groups who tried the activity once (voluntary or obligatory) repeated it again. The knowledge that they developed while piloting the activity was an important factor that influenced them to use the poster exhibition again. Examining what they said and wrote after the activity revealed that they emphasized their success in using this pedagogical technique and the ways to connect the activity to the chemistry curriculum (namely, pedagogical knowledge and curriculum knowledge) (Shulman, 1986).

Although advanced and modern scientific contents and their technological applications are appealing and have the potential to positively influence

and motivate students to enrol in science courses, they are absent from most high-school curricula, mainly because of the hierarchical nature of science (Kapon et al., 2009). If one wishes to incorporate contemporary science contents, such as the content in the poster exhibition, into high-school science lessons, one must develop a teaching pedagogy that can bridge the gap between students' pre-knowledge and the advanced content. The poster exhibition provides an opportunity to use student-centred pedagogy that is rarely used in high-school chemistry teaching (Blonder & Dinur, 2011). The concept of student-centred learning has been credited to Dewey's work (Dewey, 1902). Carl Rogers, the father of client-centred counselling, is associated with expanding this approach into a general theory of education. In his book *Freedom to Learn for the 80s* (Rogers, 1983), he described the shift in power from the expert teacher to the student learner, driven by a need for a change in the traditional environment where in this so-called educational atmosphere, students become passive, apathetic, and bored. The student-centred approach is based on the hypothesis that students who are given the freedom to explore areas based on their personal interests, and who are accompanied in their striving for solutions by a supportive, understanding facilitator, not only achieve higher academic results but also experience increased personal values, such as flexibility, self-confidence, and social skills. This approach also allows the students to have a free choice (Jenkins, 2006). They can choose the poster they would like to learn more about – an element that is rarely found in a school learning situation. The combination of advanced content knowledge and teachers' beliefs will support the teachers in using this unique poster exhibition in class (Blonder, Benny & Jones, 2014), as will be discussed in the second research question.

(2) *What influenced teachers' self-efficacy beliefs regarding their ability to use the poster exhibition, which presents cutting-edge chemistry in class?*

We found that teachers who developed a sense of ownership regarding the poster exhibition (the first cohort) or to the activity they introduced to their class (mainly cohort three) were most likely to use the poster exhibition. One conclusion that arose from decades of studying the success and failure of a wide variety of curriculum innovations is that imposed innovations are generally ineffective (Pintó, 2005), and that innovations succeed when teachers feel a sense of ownership of the innovation, or that it belongs to them and that it is not simply imposed on them (Ogborn, 2002). Pintó, Couso, and Gutié-

rrez (2005) also insisted that only if teachers feel some sense of ownership of an innovation, will they effectively carry it out in the classroom. Although a sense of ownership plays a central role in education and in teachers' professional development, not many studies have dealt with this issue. A study that followed the adaptation of European modules to the context of chemistry teaching was conducted in Israel (Blonder, Mamlok-Naaman, Kipnis & Hofstein, 2008). It was found that when the teachers were involved in developing or adapting the teaching program, they developed a high sense of ownership toward the program as well as positive attitudes. These results are correlated with our results. The teachers that were involved in developing the posters (the learning materials) or the in designing the activity with the poster exhibition developed a high sense of ownership.

However, we found a difference between the second cohort and the third cohort, although both groups developed a poster-exhibition-activity for their class. The third cohort, which was asked to pilot the activity in their class, exhibited a higher sense of ownership, more positive attitudes, and repeated the activity even when it was not part of the course requirements. One of the components for teachers (especially in implementing new activities) is teaching self-efficacy (Bandura, 1986). Teachers' self-efficacy was found to contribute to their development and sustainable changes (reference). The contribution of teachers' attitudes and more specifically, teachers' self-efficacy to changes in their teaching emerged in their first interview. Therefore, we looked for indications of teachers' self-efficacy in the follow-up interviews.

In the cyclic model for teaching-efficacy, Tschannen-Moran, Woolfolk, Hoy, and Hoy (1998) emphasized that the major factors that influence self-efficacy beliefs are cognitive interpretations of the four sources of efficacy information (namely, mastery experiences, vicarious experience, verbal and social persuasion, and emotional and physiological states). In the current study, the third cohort of teachers experienced the first source (mastery experience), which is known to be the most influential source for developing efficacy beliefs (Bandura, 1994; Usher & Pajares, 2008) of information, as was mentioned in the interviews. In addition, the teachers were asked to evaluate their teaching reflectively (in the reflective report). We would like to stress that the reflective evaluation process that the teachers underwent provides a mechanism for cognitive interpretations of the sources of efficacy information. Therefore, it supported the development of high self-efficacy beliefs.

It is therefore important to provide teachers with opportunities to develop their efficacy beliefs as well as their knowledge if one wants to introduce to schools innovative teaching materials and especially advanced up-to-date subject content.

CONCLUSIONS

The current paper presents a unique method for teaching up-to-date subject content in school science by using a poster exhibition that was designed by the teachers. The poster is a visual means that is used to briefly present scientific research at conferences (Stephen, 2011), and scientists also use the poster as a means of communicating their research. It was found that teachers were able to implement the poster exhibition in their classes and were able introduce their high-school students to cutting-edge organic chemistry. However, not all the teachers, who differ in knowledge and efficacy beliefs, actually used the poster exhibition.

The current study focuses on teachers' knowledge and beliefs that supported them in using the poster exhibition of up-to-date science in their classes. It was found that the first component that teachers need in order to introduce the poster exhibition is content knowledge (CK). Teachers (leading teachers) who lacked adequate CK found the poster exhibition to be an interesting learning experience for themselves but they did not use them in their classes. The pedagogical knowledge that accompanies the poster exhibition, namely, student-centred pedagogy was found to be less influential.

Teachers' sense of ownership and their self-efficacy beliefs were also found to be influential factors. Teachers who developed a sense of ownership during the process of designing the posters or when developing the activity for their students and piloting it in class had a higher sense of ownership towards the poster exhibition and were more likely to reuse the posters in class the next year.

ACKNOWLEDGMENTS

We would like to thank the Rothschild-Caesarea Foundation for supporting the Rothschild-Weizmann program for Excellence in Science Teaching.

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Received: February 20, 2014
Final version received: April 18, 2014
Published online: June 28, 2014