

## RESEARCH REPORT

# The “Big Ideas of Science” for the school classroom: Promoting interdisciplinary activities and the interconnection of the science subjects taught in primary and secondary education

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**Abstract:** *This paper presents the “Big Ideas of Science” set as an alternative means of organizing science educational content in an interdisciplinary way that goes beyond the traditional subject-based organizational structures. The “Big Ideas of Science” refers to a set of phrases which overarch all science subject domains and briefly describe our world; from the macrocosm to the microcosm. Building upon previous work done in the field, we introduce a set of phrases (eight) which constitute our proposed “Big Ideas of Science”. Our team carried out a research with teachers in primary and secondary education, and a small group of stakeholders, so as to examine the degree to which this set of phrases could facilitate science teaching and learning. In our research, we introduced to participants the “Big Ideas of Science” as an organization scheme that promotes interdisciplinary learning and it allows students to build more effectively on their existing knowledge by making connections between concepts and principles taught in different science disciplines. Our results indicate that such an organization scheme could be beneficial to teachers and students, as it can play or act as a backbone structure that promotes interdisciplinary science learning, and enable students to make easy connections between subjects taught. In addition, based on the feedback from stakeholders, the “Big Ideas of Science” could be helpful in promoting interdisciplinary learning, as they can be used to organize science content in schools in a sustainable way that is not affected by curriculum changes..*

**Keywords:** *Science education, Inquiry/discovery Learning Processes, Big ideas of science, interdisciplinary activities*

## Introduction

When teaching science, one of the major challenges faced by teachers is helping their students make connections between the science concepts they learn in different disciplines and how these concepts can help them explain natural phenomena that occur around them. Teachers understand the need to trigger students' curiosity and take into consideration their interests, especially when it comes to presenting subjects that seem irrelevant to them (Darby-Hobbs, 2013). Students may learn about fundamental principles; however, they often cannot understand how they are connected to the world around them or their application in explaining different phenomena and observations. Despite the fact that in many countries, several studies have shown students' views on science and technology to be quite positive, this has not yet reflected in their views on school science education (Jenkins & Pell 2006). This could also be related to the fact that teachers especially in primary education often follow a pedagogical approach that focuses on them conveying knowledge to students, rather than having students participate actively in the learning process (Fensham 2004). This teacher-centered science

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teaching approach that is deployed by many teachers often leaves students with a miscellany of facts, no sense of the big idea of why it matters, and the conception that science is a monolithic body of unquestioned and unequivocal knowledge (Osborne 2011). This is possibly one of the reasons why many studies show that pupils perceive school science as lacking relevance and it is often described as, abstract and theoretical. In order to tackle this problem and increase students' interest in science, many scholars propose the connection between formal science education and students' out-of-school experiences (Stuckey, Hofstein, Mamlok-Naaman, and Eilks 2013). Introducing an interdisciplinary organization scheme that allows students to link the concepts they learn in different science classes to a set of fundamental concepts and key principles, could help them build a more meaningful knowledge structure and increase their knowledge retention. Understanding the connection between science concepts and better understanding of fundamental and secondary principles might enable students to make better use of them when it comes to explaining phenomena in the world around them and thus find meaning in them. Increasing students' ability to explain phenomena and use the knowledge they have acquired could also play a role in increasing their appreciation and interest towards science.

At the same time, inquiry-based learning, which is a student-centered learning approach is gaining popularity among teaching communities all over the world, as many studies report its effectiveness (Ryan, 2009; Minner, Levy and Century 2010). Inquiry-based learning aspires to engage students in an authentic scientific discovery process. Such active learning strategies have proved to be among the most promising, when it comes to increasing students' learning (Froyd 2008). From a pedagogical perspective, the complex scientific process is divided into smaller, logically connected units that guide students and draw their attention to important features of scientific thinking (Pedaste et al. 2015). However, the overcrowded school curricula of many countries may make its application very limited or practically impossible. Dense curricula can potentially create a bottleneck in the application of inquiry learning and eventually discourage teachers from using it, despite its potential in increasing the changes of meaningful learning episodes for students.

In addition, as Cimer (2007) stated, meaningful learning occurs as students consciously and explicitly link their new knowledge to an existing knowledge structure since the process of trying to understand a phenomenon or explain an observation usually starts by referring to or building on our existing knowledge and based on that, try to come up with an idea that might explain it. The traditional method of fragmented teaching deprives students of the opportunity to connect facts and observations and build upon their current knowledge in order to explain them. Thus, this method acts as a barrier, not only in building students' cognition, but also in developing their problem-solving skills. On the other hand, using an interdisciplinary organization scheme of science concepts to make such connections between concepts and science disciplines can promote interdisciplinary learning, help students link their new knowledge to an existing knowledge structure as mentioned above and enable them to decipher the importance of what they learn in science classes and why it matters.

Another problem that we often find in science education is that students usually forget a large proportion of what they have learned when it comes to pure knowledge delivery based solely on concepts and theories. This could be because the curricula are often overcrowded with unfamiliar terminology and laws; they leave little room for enjoyment, curiosity, and a search for meaning (Sjøberg 2002). Time constraints, which could stem from dense curricula, do not allow enough time for students to reflect on and process they have been taught (Faught et al. 2016). Moreover, overcrowded curricula allow very little time (if any) for students to absorb what they have learned and assess its importance (Osborne et al. 2001).

Furthermore, the pieces of knowledge that do remain are random aspects of the curriculum, which are not necessarily the most fundamental ones and frequently misplaced in terms of connections to natural phenomena and its practical effects. In fact, students often assess the importance of what they learn in school based on misleading criteria. For example, students may assess the significance of a subject based on criteria like the possibility of questions coming from that subject in an upcoming test or the length of time spent on it in class by the teacher and not on how fundamental the subject matter might be. Students' difficulty in assessing

the importance of a piece of information, could also be due to the fact that, curricula do not often focus on the context and the connection between what is taught in the science class and the world. A context-based curriculum, however, could contribute not only in identifying the importance of what is learned, but also in improving students' interest and a positive attitude towards science in general and in particular disciplines, for example, chemistry (Mandler, Mamlok-Naaman, Blonder, Yayon, and Hofstein 2012).

An interdisciplinary organization scheme can act as a 'backbone structure' which comprises of fundamental concepts and principles that allows students to make easy connections between previous and new knowledge, as well as between science concepts taught and phenomena present in everyday life thus giving these concepts a relative context. It can also help teachers save time with overcrowded curricula creating collaboration opportunities across different subject domains where common concepts can be gathered and presented under a common framework. In order to meet the needs of students as effectively as possible, this backbone structure would have to be interdisciplinary, overarching all science disciplines, allowing students to understand that concepts in science are transdisciplinary and also across grade levels, are deployed to explain and make sense of the same thing; the world we live in. By going back to the same knowledge structure every time a new concept is introduced, students may find it easier to understand this new concept, thus making the learning process more efficient and less time-consuming. Additionally, this revisiting of the same knowledge structure and the connections between concepts can increase knowledge retention and potentially enable students to assess the importance of each concept based on more meaningful criteria like its role in understanding phenomena and its connection to fundamental principles.

Such a structure, being interdisciplinary, could also be the starting point in fostering the collaboration between teachers of different disciplines to use activities with their students that approach the same subject from different viewpoints. Such activities could ideally be designed using an inquiry approach, which is known to improve students' knowledge retention (Dresner, de Rivera, Fuccillo, and Chang 2014). The combination of an interdisciplinary learning context with the inquiry approach can potentially increase students' interest in science, and consequently their scientific discovery skills, as research shows that such skills are evolving continuously and are more likely to be improved, when motivation and interest in science is fostered (Keselman 2003). This interdisciplinary inquiry-based type of learning could also allow students to explore more in depth, the subjects at hand and gradually modify their understanding of science from a set of isolated disciplines which are about unrelated topics and concepts to a coherent and well-orchestrated mechanism for making sense of our world.

In a report published in 2010, a set of ten principles underpinning the science education of all students is presented based on the work of a group of scientists, engineers and science educators. According to this report, "students should be helped to develop 'big ideas of science' and about science that will enable them to understand the scientific aspects of the world around and make informed decisions about the applications of science." (Harlen 2009, p.4).

The "Big Ideas of Science" are a set of core ideas that connect phenomena and principles. They are reference points students can come back to in order to understand the relation between phenomena and principles. Grasping the big ideas enable learners to individually understand various aspects of the world around them, both the natural environment and that created through the application of science (Harlen, 2009). A big idea may be thought as a linchpin, one that is essential for understanding. Without grasping the big idea and using it to hold together related content of knowledge, we are left with bits and pieces of inert facts that cannot take us anywhere (Wiggins and McTighe, 2005).

We believe that a set of principles like the "Big Ideas of Science" could be the interdisciplinary organization scheme of science concepts discussed above, help tackle the problems mentioned earlier and help teachers change their teaching style towards a more interdisciplinary approach. Such a set of principles could play the role of the backbone structure of core science concepts, one that could be used by teachers and students as a reference point when teaching science across school grades and help students attach new pieces

of knowledge to an existing knowledge structure. In this context, a “Big Ideas of Science” set could act as a compass for students towards understanding better, the significance of what they learn in school. In addition, keeping a constant cognitive reference point like the “Big Ideas of Science” set, and connecting each piece of new knowledge to it, may increase the chances of students to acquire a deeper understanding of facts and concepts and be able to retrieve and apply them in the future. By having a fixed reference point of fundamental ideas, students could also be in better position to evaluate what they learn at school, understand its importance and consequently find more meaning in it. Thus, although students still have to face overcrowded curricula they could have a guide that could help them distinguish the most fundamental concepts from secondary ones and understand how they are related and how they are used to explain phenomena in the world around them. Helping students identify and organize in their minds the concepts they learn, leads to a better ability of retrieving them and using them not only in the context of school but also in the outside world. A clearer idea of scientific concepts and how they are related can help students understand and identify more easily the laws and principles behind a natural phenomenon. In this sense, the “Big Ideas of Science” can be used not only as the means to connect science concepts in an interdisciplinary way, they could also facilitate students in connecting science concepts taught in school to the world around them by enabling them to better understand and identify the principles and laws behind natural phenomena.

Additionally, teachers of different science disciplines could potentially use a set of “Big Ideas of Science” in order to collaborate and find connections between the concepts they teach. By collaborating, making references to each other’s classes and working together on interdisciplinary activities that focus on concepts connected through a big idea, teachers can increase students’ interest and speed up the learning process as students recall existing knowledge, thus making it easier to understand and comprehend the new subject at hand. This way, there is more room for inquiry and students can have more time to spend on reflecting and processing new knowledge and make it part of a bigger knowledge structure.

With this in mind, we conducted a study to check whether a set, like the one introduced in Harlen’s report could be used as an organization scheme that presents science concepts as a collection of related principles in a way that goes beyond the typical organization of science curricula and connects concepts in an interdisciplinary way. In this context we also made an effort to use the “Big Ideas of Science” as a tool to organize science educational content and resources, to present tools and activities in a coherent interdisciplinary format. Such a content organization could facilitate teachers in different science subject domains to identify common grounds on which they can build interdisciplinary activities. If used in class, it can also play the role of a reference point for students, one to which they can go back to every time they learn something new and through that establish connections with previous knowledge.

Our work was conducted within the framework of the “Go-Lab: Global Online Science Labs for Inquiry Learning at School” project (<http://www.go-lab-project.eu/>), which aimed to establish an online portal that facilitates the federation of existing virtual and remote science labs (De Jong et al. 2014; Govaerts et al. 2014). Our study’s starting point was to examine whether a set like Harlen’s “Big Ideas in Science Education” could be used in the Go-Lab repository (<http://www.golabz.eu>), as means of organizing online science labs and related activities.

The work presented in this paper is part of the work done in an effort to map and sample teachers and teacher trainers’ understanding of the “Big Ideas of Science” concept, and investigate whether a set of such ideas could be helpful for them as a tool used to connect science concepts; especially concepts taught in different science subject domains and school grades. More specifically, in this paper we present the results from the second round of the validation process our team carried out in which we used the updated “Big Ideas of Science” set that was produced after concluding a first round of validation. We also present teachers’ views on its use in teaching science in school. In addition, we also investigated teachers’ views on the potential use of the “Big Ideas of Science” as the means of organizing educational content within the Go-Lab repository and through it promote interdisciplinary learning.



## Methodology

### *Starting point and background work*

The trigger for this work was the report already mentioned above edited by Wynne Harlen in 2010, the “Principles and Big Ideas in Science Education”. We started by examining whether the ten principles set presented could be used to organize the content of the Go-Lab repository. To achieve this, we began by mapping the science vocabulary used in the Go-Lab repository to the ten big ideas mentioned in the report (Harlen, 2010).

This work was based on previous development implemented in the framework of the Open Discovery Project (ODS Project – D4.2). During this process, we found out that certain science terms from the science vocabulary, for example those that are related to quantum phenomena could not be clearly categorized under one from the current set of ten ideas. To this end, we decided to review several other similar sets from the bibliography (on science as a whole or on each science discipline separately) and to propose our own Go-Lab “Big Ideas of Science” set. The produced set was used to propose a methodology for organizing online labs and inquiry activities in the framework of the Go-Lab project (Zervas et al. 2014). Based on the definition used, the term “Big Ideas of Science” refers to “a set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena”. (Zervas, 2014; Dikke et al. 2014).

After the Go-Lab “Big Ideas of Science” set was produced, it was mapped again to the Go-Lab science vocabulary to make sure that it covered all science terms included. Once that was done, we conducted one validation round to record teachers’ understanding of the concept, the degree to which they feel it can be used to connect science subjects as well as science subjects to phenomena met in everyday life and its usability as a recommendation system for organizing online science labs and related activities. The set was initially validated with science teachers of 93 European schools (Tsourlidaki, Zervas, Sotiriou, and Sampson 2015). In the sections below, we present the results from the second round of our validation process. For the second round of the validation process we used the same methodology and the updated “Big Ideas of Science” set (presented below) that was produced after concluding the first round of validation.

### *The bottom-up approach: teachers’ views about the “Big Ideas of Science”*

#### *Study methodology*

As mentioned earlier, the aim of our work was to sample the opinion of teachers and their trainers on the concept of the “Big Ideas of Science”. Our research plan included questions that aimed to deduce how familiar our participants were with the term, the “Big Ideas of Science” prior to our workshop, their opinion on the Go-Lab “Big Ideas of Science” set and to what degree a set like that could be beneficial to them when teaching science to their students. In our set of questions, we also included some that aimed to record the degree to which teachers fill it is important to connect science concepts taught in different disciplines and different grades as well as how important it is for them to provide a context for their students by connecting what they learn in school to the world around them and phenomena from everyday life.

In order to increase participants’ interest, we designed a hands-on and minds-on workshop, where participants were given the opportunity to reflect on the concept of the “Big Ideas of Science”, what would constitute a set like that and collaborate with other teachers and their trainers to produce a set of “Big Ideas of Science” of their own. The validation workshops reported in this paper had three parts which were similar to the workshops reported in previous work (see Tsourlidaki et al. 2015):

*Introductory part:* In this part, participants were given a presentation on the concept of the “Big Ideas of Science”. The presentation laid emphasis on the fact that students often forget most of the knowledge they have acquired at school, on the idea of connecting subjects taught in different science disciplines, as well as the need to design interdisciplinary activities for students and to have a reference point which students could use to make connections between different concepts and phenomena. It is worth noting that, although, the concept of the big ideas was discussed, no particular set was presented to the participants. In addition, prior to

the presentation, a preliminary questionnaire was given to the participants to fill, so as to deduce the teachers' current knowledge on the "Big Ideas of Science" and their opinion about connecting what they teach in school with other subject domain, content from previous and coming grades as well as everyday life.

*Brainstorming part:* In this aspect, teachers were given time to reflect and think of concepts that in their opinion, should be involved in a "Big Ideas of Science" set. The question posed to them was: "If it was up to you to choose the eight or twelve (as many as you like) most important science concepts to teach your students; a set of concepts that your students would remember for the rest of their lives, what would these concepts be?" After writing down their ideas, participants were asked to share them with the rest of the team, everyone's ideas were reviewed and collaboratively, clusters of similar concepts and ideas were formed. Participants then formed groups; each group was invited to exchange ideas and put together a 'Big Idea' based on one cluster of concepts. The aim of this activity was to involve the teachers in a hands-on and minds-on activity that would motivate them in reflecting on the notion of the big ideas and think about what could constitute a big idea, based on their own opinion and experience. Thereafter, when we later on presented our own set of big ideas, the teachers could go through it and assess it more effectively based on their own ideas, thus, providing us with meaningful and concrete feedback.

*Assessment part:* Once the brainstorming part was completed, various groups presented their "Big Ideas" which were then discussed with the entire group. The Go-Lab set was then presented, and compared with the participants' Big Ideas. The presentation of the set also included a brief demonstration on how such a set could be used to connect different activities and online labs. Thus, give room and ideas for combining activities from different domains that fall under the same big idea. The use of such a set in the science classroom was then discussed, so as to determine to what degree teachers believe that this could be a useful tool for their students in understanding the connections between different phenomena and what they learn at school and their everyday life. The participants' opinions were also sampled with the use of a second questionnaire.

## Results and findings

For our research, we conducted 19 workshops in different European countries, engaging 352 teachers in total. We conducted two rounds of the workshops. In the first round, we gathered input from 186 participants that participated in 11 of the workshops we carried out. After completing the first round of validation, we revisited our set of "Big Ideas of Science" and updated it based on the feedback received. While revising our set, we took into consideration the suggestions of teachers gathered from the questionnaires and in particular: a) their individual answers on the "Big Ideas of Science" according to them; b) the "Big Ideas of Science" produced by the brainstorming collaborative groups; c) their comments on the current Go-Lab set of "Big Ideas of Science"; d) the overall discussions during workshops.

In the second round of validation, which was comprised of 9 workshops, we followed the same methodology; the only difference being that we now used the updated version of our "Big Ideas of Science" set. In the second round, we involved another 166 participants. The results of our work are presented below.

### *Participants' profiles*

Our workshops were conducted in Bulgaria, Cyprus, Greece, Italy, Portugal, Romania, Spain, the Netherlands, and UK. However, 6 out of the 19 workshops had international participants coming from several other countries. The total representation of participants comes from Austria, Belgium, Bulgaria, Croatia, Cyprus, Estonia, Germany, Greece, Hungary, Italy, The Netherlands, Portugal, Romania, Spain and UK. From our sample, 23.7% were trainers of science teachers. The rest of them were to their vast majority science teachers.

With regards to the general characteristics of our sample, we can see that there is a slight majority of women compared to men (61% Female, 39% Male). This is due to the fact that in some countries, like Italy for

example, the vast majority of teachers who teach science are women. Aside that, majority of the teachers in our sample population are science teachers (94%) and 82% of them teach students between the ages of 9 and 18 years. In addition to this information, 63% of the teachers in our sample has at least a master's degree and 67% has more than 11 years of teaching experience, so they are considered to be quite experienced teachers.

#### *Participants' familiarity with the concept "Big Ideas of Science"*

At the beginning of every workshop, participants were invited to fill in a preliminary questionnaire so as to document whether they were familiar with the concept "Big Ideas of Science". As it was our aim to investigate whether a set of Big Ideas could be helpful for them to connect science concepts we also included questions about the degree to which they believe it is important to relate what they teach their students to concepts that students have learnt in the current or past grades, within the same or other science domains as well as to natural phenomena. These questions were included as our study was conducted under the framework of using of the "Big Ideas of Science" as an organization scheme for connecting science concepts from different grades and subject domains within an interdisciplinary framework. Thus, teachers' views on the importance of connecting science concepts in such a way (and how these views changed or not after participating in the workshop) was of great importance for our team.

This questionnaire was used in both rounds of workshops. Below, we present the results of our pre-workshop questionnaire for the entire sample population (352 questionnaires).

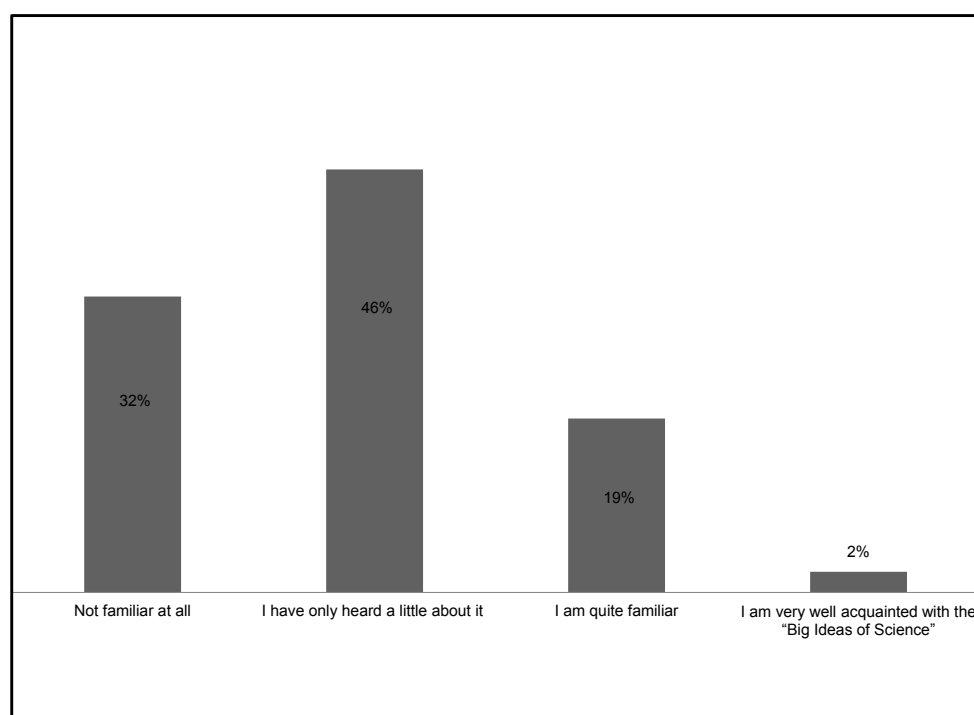


Figure 1. *Participants' familiarity with the concept of the "Big Ideas of Science"*

Table 1.

## Teachers' opinion on the definition of the "Big Ideas of Science"

<i>Which of the following definitions do you believe describes best the "Big Ideas of Science"?</i>	<i>Number of responses</i>	<i>Percentage</i>
A. A set of ideas that briefly outline science's greatest achievements and discoveries.	48/352	14%
B. A set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena.	207/352	59%
C. A set of concepts that outline how science works and what principles (ethical, social, economic and political implications) it is submitted to.	46/352	13%
D. A set of proposals that demonstrate to teachers how to teach science in the most successful and efficient way.	51/352	14%

As seen from the results above, although the majority of participants have enough experience in teaching science (15% of them have between 6 and 10 years of experience and 67% of teachers have more than 11 years' experience), 78% of them are basically not familiar with the concept of "Big Ideas of Science", so we know they do not use this approach in their everyday teaching. However, despite the high percentage of people who are not familiar with "Big Ideas of Science", 59% of them have selection B as their selected definition as presented in table 1 which is the definition of "Big Ideas of Science" given in this research (Dikke et al. 2014). This could indicate that, although, teachers are not very familiar with the term "Big Ideas of Science", it is still close to their understanding and they can relate with it and understand what it stands for.

As we consider the "Big Ideas of Science" to be a tool that could help students increase their ability to make connections between different science concepts and phenomena from our everyday life, the four remaining questions of the pre-workshop questionnaire aimed to record how often teachers tend to connect what they teach their students to everyday life and to other science subjects respectively, as well as to identify to what degree the teachers believe that these connections are important to be made in the science class. The results are presented in the figures below.

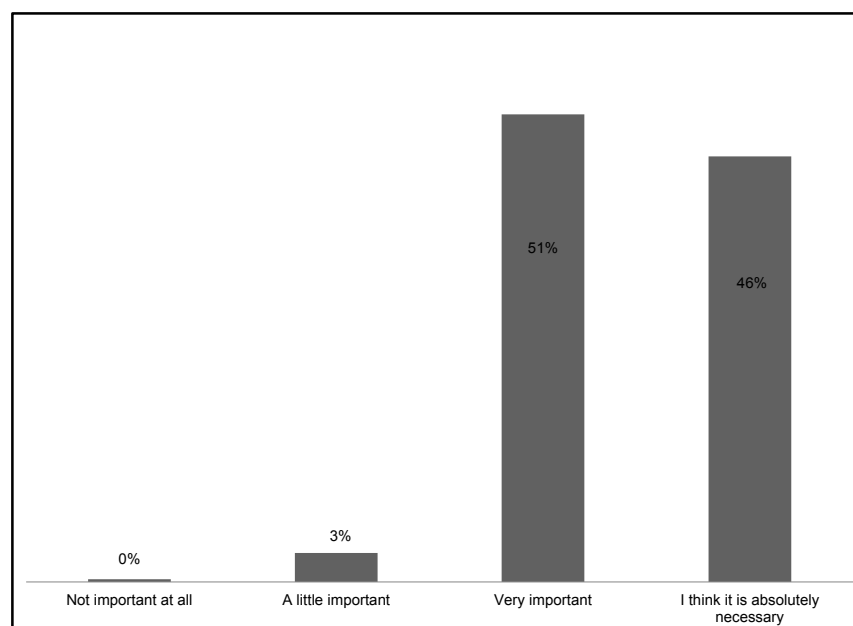


Figure 2. Participants' opinion on the importance of connecting the science subjects taught at school with other subjects students have been taught in the present or past years



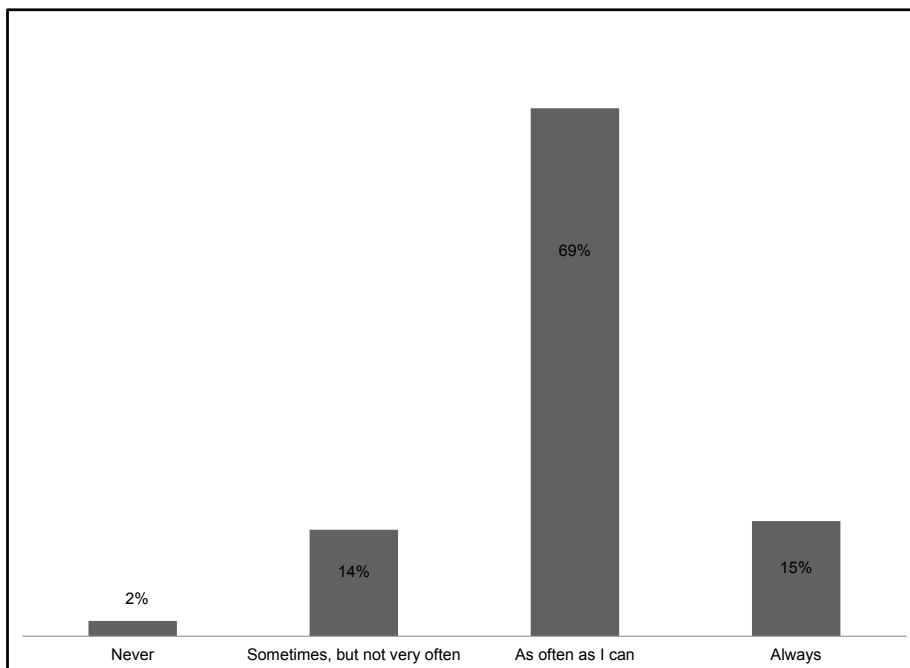


Figure 3. Participants' answers on how often they try to connect any given subject they teach in class with other subjects that students have been taught in the present or past years

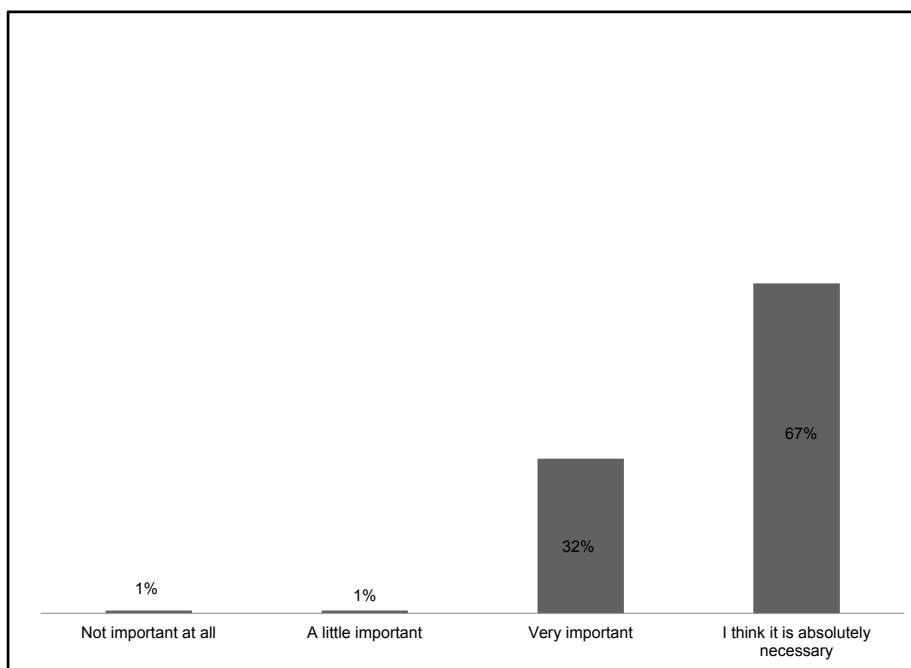


Figure 4. Participants' opinion on the importance of connecting the science subjects taught in school with everyday life phenomena and the world around us

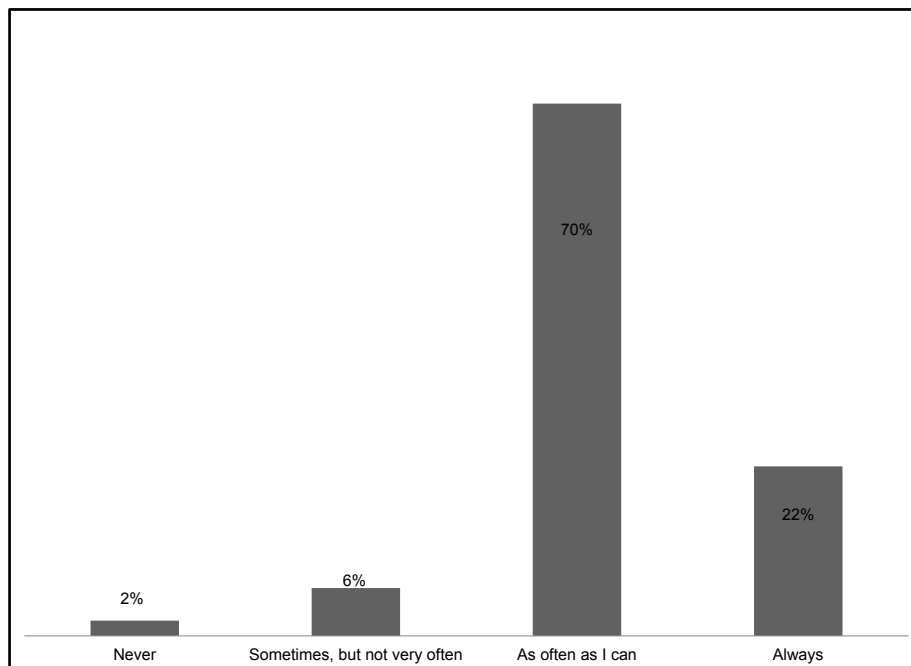


Figure 5. Participants' answers on how often they try to connect any given science subject taught in class with everyday life phenomena and the world around us

As seen in the figures above, teachers believe that both issues; connections between science subjects taught in different grades and connections between what students learn at school with everyday life are of high importance. This also explains why they try to make these connections as often as they can. More particularly, teachers believe that the most important out of the two, is building bridges between the school science classroom and everyday life. This finding is in accordance with the idea that one of the most fundamental goals of schooling is to help students apply what they have learned in school to everyday settings of home, community, and workplace (Bransford 2000). Moreover, based on the fact that teachers have also stated that they are not very familiar with the concept of “Big Ideas of Science”, we can assume that they try to make these connections either using some other approach or in an uncoordinated way. In none of our workshops, did any participant mention anything about using a similar approach or another set of “Big Ideas of Science” as a reference point.

In the brainstorming part of our workshops, teachers were invited to think about what should be the “Big Ideas of Science” in their opinion. Thus, teachers wrote down concepts and ideas which they believed should be a part of a Big Idea of Science. During the first round of workshops, from this activity, we obtained 747 single answers from participants, regarding concepts and phenomena that according to them, should be included in a Big Idea. These answers were categorized and checked one by one to see if they were covered by our current set. In total, we have found that 32 answers (4%) were not entirely covered by our current set. These answers belonged to three categories; a) quantum mechanics; b) relativity theory; and c) time and scales of the universe. In total, the amount of answers that were not covered by our set was small, which means that no major changes were required. In addition, we gathered 44 “Big Ideas of Science” phrases from the group work of the teachers. These sentences varied a lot in terms of phrasing compared to our own set, but their meanings did not deviate from our own “Big Ideas of Science” set. Finally, after presenting our “Big Ideas of Science” set and asking teachers to comment on it and compare it with the Big Ideas produced by the groups during the workshop, we also gathered 74 additional comments on our set, 54 of which included concrete suggestions. After taking into consideration the suggestions of teachers gathered from the questionnaires and in particular: a) their individual answers on what, in their opinion, are the “Big Ideas of Science”; b) the “Big Ideas of Science” produced by groups of teachers during the workshops; c) their comments on the current Go-Lab set of “Big

Ideas of Science”; and d) the overall discussions during workshops .We made some revisions to our current set of “Big Ideas of Science” and proposed a set of modifications. Aside from minor modifications in the writing of each idea, the main modification we made was to change their presentation a little. As most of our “Big Ideas of Science” can be a bit extensive, therefore, in the spirit of serving the needs of teachers who requested shorter and simpler “Big Ideas of Science”, we decided to divide each Big Idea of Science into two parts. The first part is a short sentence which contains very briefly, the essence or the core part of a Big Idea of Science. The second part is the remaining explanatory text of each Big Idea of Science as it is now, which basically compliments the first sentence and completes the meaning of the “Big Ideas of Science”. We assume that such a ‘hybrid’ approach could be more beneficial to students as it can be concise enough to allow them remember the key phrases and at the same time, explanatory enough to allow teachers and students to make easier connections between different phenomena and concepts. The initial and updated Go-Lab “Big Ideas of Science” set are presented below.

Table 2.

The updated set of the Go-Lab set of “Big Ideas of Science”

<i>Initial Go-Lab “Big Ideas of Science” set</i>	<i>Updated Go-Lab “Big Ideas of Science” set</i>
1. Energy can neither be created nor destroyed. It can only be transformed from one form to another. The transformation of energy can lead to a change in state or motion.	1. Energy can neither be created nor destroyed. It can only be transformed from one form to another. The transformation of energy can lead to a change in state or motion. Energy can also be converted to mass and vice versa.
2. There are four fundamental interactions/forces in nature; gravitation, electromagnetism, strong-nuclear and weak nuclear forces. All phenomena are due to the presence of one or more of these interactions. Forces act on objects and can act at a distance through respective physical field, causing a change in motion or in the state of matter.	2. There are four fundamental interactions/ forces in nature. Gravitation, electromagnetism, strong-nuclear and weak nuclear forces. All phenomena are due to the presence of one or more of these interactions. Forces act on objects and can act at a distance through respective physical field, causing a change in motion or in the state of matter.
3. The Universe is comprised of billions of galaxies, each of which contains billions of stars and other celestial objects. The earth is a very small part of the Universe.	3. Earth is a very small part of the universe. The Universe is comprised of billions of galaxies, each of which contains billions of stars (suns) and other celestial objects. The earth is a small part of the solar system with the Sun in its centre, which in turn is a very small part of the Universe.
4. All matter in the Universe is made of very small particles. They are in constant motion and the bonds between them are formed by interactions between them.	4. All matter is made of the same very small particles. They are in constant motion and the bonds between them are formed by interactions between them. Elementary particles as we know, form atoms and atoms form molecules. There is a finite number of types of atoms in the universe which are the elements in the periodic table.

- |                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>5. All matter and radiation exhibit both wave and particle properties.</p>                                                                                                                 | <p>5. In very small scales, our world is subjected to the laws of quantum mechanics.</p> <p>All matter and radiation exhibit both wave and particle properties. We cannot simultaneously know the position and the momentum of a particle.</p>                                           |
| <p>6. Evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct). Organisms pass on genetic information from one generation to another.</p>     | <p>6. Evolution is the basis for both the unity of life and the biodiversity of organisms (living and extinct).</p> <p>Organisms pass on genetic information from one generation to another.</p>                                                                                         |
| <p>7. Organisms are organized on a cellular basis and require a supply of energy and materials. All life forms on our planet are based on a common key component.</p>                         | <p>7. Cells are the fundamental unit of life.</p> <p>They require a supply of energy and materials. All life forms on our planet are based on this common key component.</p>                                                                                                             |
| <p>8. Earth is a system of systems which influences and is influenced by life on the planet. The processes occurring within this system shapes the climate and the surface of the planet.</p> | <p>8. Earth is a system of systems which influences and is influenced by life on the planet.</p> <p>The processes occurring within this system influence the evolution of our planet, shapes its climate and surface. The solar system also influences Earth and life on the planet.</p> |

In the second round of workshops, as mentioned above, we followed the exact same procedure, the only difference being that in this round, we used the updated version of our Big Ideas set. In this round, we gathered 505 single terms from the brainstorming session. We have found that all single small ideas are covered by the updated Go-Lab set with the exception of the 5 (1%) answers that refer to time and the scales of the universe. However, time and the scales of the universe are two concepts that are connected to every single one of the other concepts and instead of adding another Big Idea, it would make more sense to represent the current set of Big Ideas in the scales of time and space. In this round, another 44 “Big Ideas of Science” phrases were collected from the group work of the teachers. Like in the previous round, although varying in terms of phrasing, teachers’ Big Ideas were in accordance with our own set in terms of meaning. About 31 out of 44 phrases (70%) were again brief and laconic. Finally, we also gathered another 73 comments and suggestions from participants, 12 of which were about minor changes. However, all suggestions had a very low number of occurrences (less than 3) and thus, we concluded that no further changes were needed at this point.

During the hands-on part of the workshop teachers had the chance to go through the proposed set of big ideas, discuss it with their peers, reflect on it based on the curriculum they teach and compare it to the big ideas they produced during the brainstorming part. Based on that experience we asked them to what degree they fill that the proposed set of “Big Ideas of Science” is achieving its purpose; offering a set of cross-cutting scientific concepts that describe the world around us and allow us to conceive the connection between different natural phenomena and that could be used as a reference point to connect science concepts in an interdisciplinary way. Below, we present teachers’ overall opinion on the Go-Lab “Big Ideas of Science” set, on the use of such a set in the science classroom and on its use as a content organization system. The results in the graph below indicate that the teachers and their trainers that participated in our research are strongly in favor of the Go-Lab set of “Big Ideas of Science”. The results of the workshops during the second round also indicate that there is a shift in participants’ opinion towards higher rating of the Go-Lab updated set. In round 1, 66% gave a score of 4 out of 5 and 22% gave 5 out of 5 (4.1 average rating).

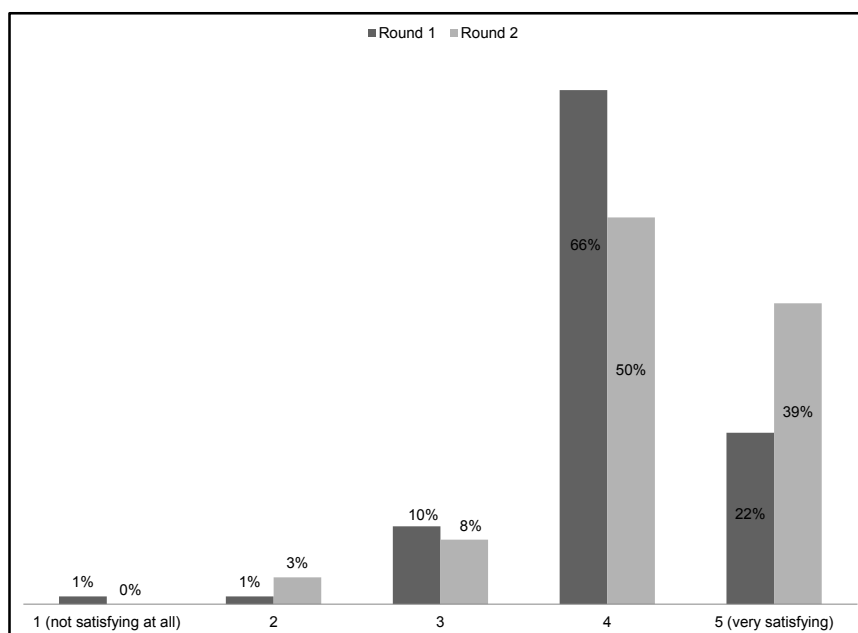


Figure 6. Participants' answers on rating Go-Lab "Big Ideas of Science" set

In round 2, the percentage giving score 4 out of 5 has decreased to 50% (11% drop) and at the same time the percentage of participants giving a score 5 out of 5 has increased to 39% (14% increase, 4.2 average score). This shift leads us to believe that the updated version of our Go-Lab set, which was done based on teachers and teachers' trainers' recommendations from the previous workshops, is more appealing to teachers and suits their needs even better when it comes to using in as an interdisciplinary organization scheme for connecting science concepts.

Figure 7 indicates that 94% of our participants feel that the "Big Ideas of Science" are important or very important when it comes to teaching science. As the "Big Ideas of Science" are meant to be used as a means to connect different science subjects, it is worth comparing Figure 2 to Figure 7. The data presented in these two graphs contain very similar questions. In the pre-questionnaire, in the question "How important do you believe it is to connect the science subjects taught in school with other subjects that students have been taught in the present year or past years?" 51% of the participants have answered "Very important" and 46% of them have answered "I think it is absolutely necessary" (we obtained a total of 97% positive feedback).



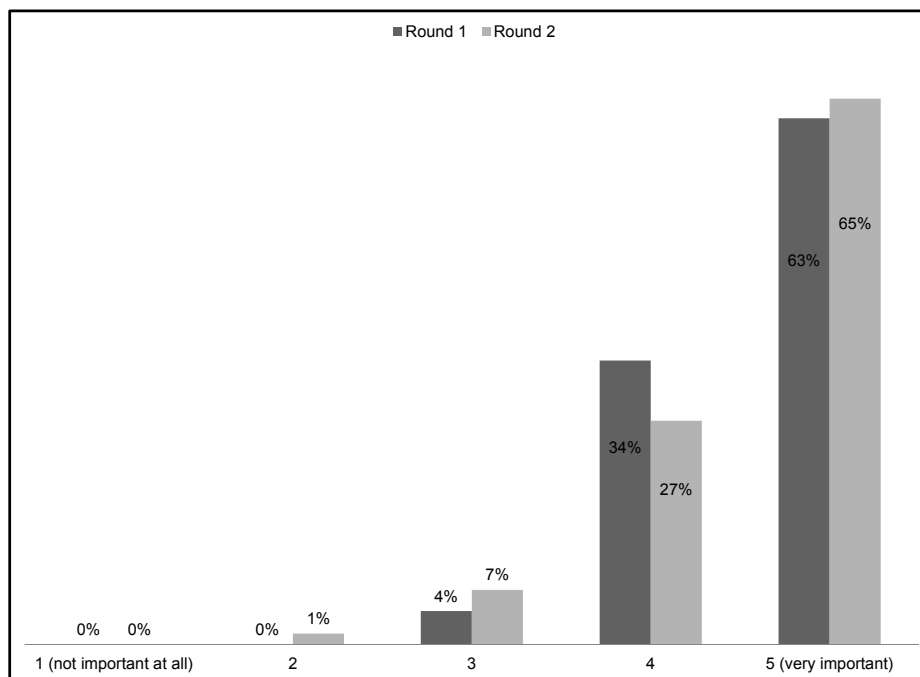


Figure 7. Participants' opinion on the importance of the "Big Ideas of Science" related to teaching science

In the post-questionnaire, in question "How important do you regard "Big Ideas of Science" to be, when it comes to teaching science?" 30% of the people gave 4 out of 5 (5 being "Very Important") in the Likert scale and 64% of them gave 5 out of 5 (total of 94% positive feedback). These figures and the swift (18%) of participants' opinion towards a higher rating in the latter question may also indicate that their participation in our workshop has contributed in strengthening their view on the importance of connecting different science subjects in the classroom. In addition, given the high rating the "Big Ideas of Science" have received, we can also conclude that the Go-Lab set of the "Big Ideas of Science" could play the role of a backbone structure in connecting science subjects.

In most educational repositories, the educational content is primarily organized according to science discipline and age group. When selecting a resource some systems recommend additional content based on the science subject or age group, however these recommendations are rarely cross-discipline or interdisciplinary. Teachers cannot find content in such repositories organized using an interdisciplinary scheme allowing them to combine activities coming from different disciplines and that could be used to demonstrate to their students underlying connections between science concepts taught in different science classes. Thus, teachers' opinion during workshops done in round 1, as seen in Figure 7, led us to add an additional question to the post questionnaire used during round 2. Since teachers believe that the "Big Ideas of Science" can be important in teaching science, what we wanted to further investigate was whether a recommendation and organization system of educational content using the "Big Ideas of Science" would be helpful to them when teaching for retrieving and/or combining educational content and activities within an interdisciplinary context of teaching science. The results of this question are presented below in Figure 8.

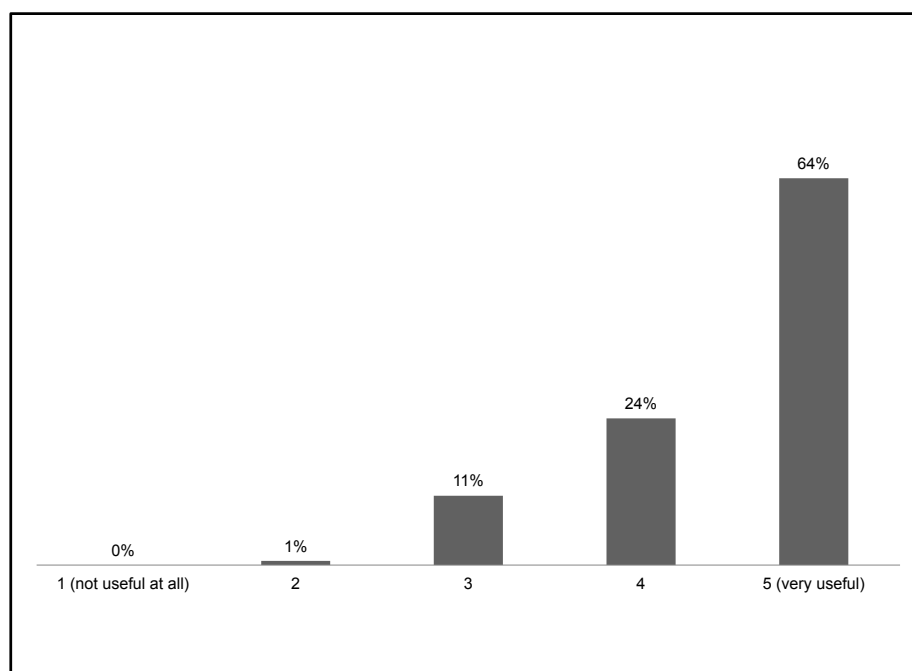


Figure 8. Participants' opinion on the usefulness of a "Big Ideas of Science" as a recommendation system

As it can be seen in the figure above, the results are very positive, as 88% of the participants believe that such a recommendation system could be useful or very useful. Given these results, we strongly believe that the presence of the "Big Ideas of Science" set in an educational repository can be very beneficial to teachers, especially if used as an organization and recommendation system that connects activities and resources within an interdisciplinary framework.

## Conclusion

Building a knowledge structure for students and giving them the opportunity to attach each piece of new knowledge to it consciously and explicitly can contribute a great deal to meaningful learning (Cimer, 2007). When it comes to learning science in particular, such a knowledge structure would work to the benefit of students if it was interdisciplinary, covering all science disciplines. Such an interdisciplinary organization scheme would give the opportunity to students to assess the importance of concepts taught, identify the fundamental ones and understand the connection between science concepts taught in different science classes that may seem irrelevant but in fact have an important underlying connection. Such connections can enable students to understand that all science disciplines are there to help us make sense of our world. By using a set of core big ideas as reference system when teaching science, teachers can enable their students to increase their knowledge retention, look at the bigger picture and understand various aspects of the world around them (Harlen, 2009).

Additionally, this core set of interdisciplinary "Big Ideas of Science" can help teachers swift to a more interdisciplinary teaching style and support collaboration between them. Interdisciplinary learning can help teachers raise students' interest in science – a need teachers are fully aware of (Darby-Hobbs, 2013) – and allow them to build collaborative activities that study the same concept from different viewpoints. This way, the use of the "Big Ideas of Science" as an organization scheme to promote interdisciplinary science learning can contribute in providing a more meaningful context to science curricula and thus improve students' curiosity and a positive thinking towards science (Mandler, Mamlok-Naaman, Blonder, Yayon, and Hofstein 2012).

The study presented in this paper is part of the work done on validating the Go-Lab set of “Big Ideas of Science” through the realization of relative workshops with teachers and teachers’ trainers. More specifically we set out to record teachers’ and teachers’ trainers’ understanding of the “Big Ideas of Science” concept, and find out whether such a set of ideas could be helpful for them if used as a tool to connect science concepts; especially concepts taught in different science subject domains and school grades as well as a recommendation system tool for finding activities that are related under an interdisciplinary framework within the Go-Lab repository of online science labs and activities.

The analysis of our data indicates that the majority of teachers, even many with several years of experience in teaching science, are unaware of the term “Big Ideas of Science”. However, the concept is close to their understanding and they can easily relate to it. In addition, the vast majority of teachers and teachers’ trainers in our sample believe that connecting science subjects taught in school to each other and to the world around them is very important for students and thus, they try to make these connections in their class as often as possible. This tendency is in accordance with students’ views who also prefer a science education closer to everyday life (Aikenhead, 2006).

Based on the input and comments gathered from the teachers who participated in the first round of validation, we made small modifications to our original set of Big Ideas. The results from the second round of validation during which we used our updated “Big Ideas of Science” set and more specifically based on the question about evaluating our set, showed that the updated set of Big Ideas had a higher score indicating that the updated version was closer to teachers understanding and perception of the concept compared to the original version. Evidence also show that the updated version of the Go-Lab set had a greater impact on workshop participants, as they gave it a higher score compared to the results of the first round when asked to evaluate our Big Ideas of Science set. In total, 82% of the teachers who participated in our workshops gave the Go-Lab “Big Ideas of Science” set, a score of 4 or 5 out of 5, while 94% of them believe that the concept of the “Big Ideas of Science” is quite an important notion and could be a useful tool when it comes to connecting science concepts in class for students, especially when concepts come from different science disciplines. This could mean that the “Big Ideas of Science” could give teachers the capacity to create interdisciplinary learning experiences that allow students to integrate knowledge, skills, and methods of inquiry from several subject areas, which is a pivotal skill towards successful teaching (Council, T. A., & National Research Council, 2001).

Overall, teachers’ answers and comments during discussions indicate that they are not provided with the means that will allow them to collaborate effectively and be in a position to work on making connections, between science subjects. According to them, a set of “Big Ideas of Science” like the one presented in the framework of the Go-Lab project could play the role of such a backbone structure that the teachers can use in their class to communicate the matters under discussion in a more constructive way, thus, allowing students to build on existing knowledge and experience.

In addition, when used in the framework of interdisciplinary activities, the “Big Ideas of Science” set could facilitate students in making stronger and deeper connections between facts, concepts and phenomena coming from the same or different science disciplines. They can help learners possess relevant concepts and propositions that can serve to anchor the new learning and assimilate new ideas, which is one of the requirements of meaningful learning (Novak, 1993). However, the introduction of such an approach would require properly designed materials for students and a training framework for teachers. If used as a reference guide for connecting science concepts, the “Big Ideas of Science” could also be used as a way to organize science interdisciplinary activities and help teachers from different disciplines collaborate using one or more big ideas as common ground. An organization of science content using the “Big Ideas of Science” goes beyond curricula thus making it unaffected by the constant changes that occur in the science curricula of many countries. In an era when teachers search online for inspiration for their activities, they communicate with teachers from other countries and share ideas and activities with them, such a “curriculum-proof” organization of content and activities could have significant potential.

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