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PEDAGOGICALLY DESIRABLE SCIENCE EDUCATION: VIEWS ON INQUIRY-BASED SCIENCE EDUCATION IN TURKEY

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Abstract. *The aim of this research is to investigate the aspects of science education, which are pedagogically desirable for the individual in the society of 21st century. The research was conducted by Curricular Delphi Study method in three rounds with international comparisons. In the first round, an open-ended survey was used, and in the next two rounds the instrument was structured to answer the refined research questions of the study, such as the priorities and practices towards the inquiry-based science education. The paper reports on the findings of a survey collected from 125 stakeholders of science education, including scientists, science educators, and education administrators from Turkey. In the results of the differentiated analyses according to the sample groups, all stakeholders emphasize the role of science education in the survival of a country. They all put a great emphasis on the curriculum. The stakeholders emphasized the significance of engagement with the interdisciplinary relations of the sciences, their findings and their perspectives with regard to their role in enhancing individual intellectual personality development. It is suggested that scientific inquiry includes the ability to consolidate the inquiry processes with scientific knowledge, scientific reasoning and critical thinking to advance scientific knowledge.*

Key words: *inquiry-based, science education, Delphi method.*

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Introduction

The current goal of science education in many countries around the world is to educate people towards scientifically literate society (e.g. Council of Ministers of Education, Canada [CMEC], 2013; European Commission [EC], 2007; Ministry of National Education in Republic of Turkey [MEB], 2013; National Research Council [NRC], 2011), and this aim is emphasized for more than 14 years in the course of international studies such as PISA and TIMSS (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009; Organisation for Economic Co-Operation and development [OECD], 2001, 2004, 2007, 2012, 2015). Scientific inquiry, both the understanding about and the practice of which, is considered as an integral element of scientific literacy (Lederman et al., 2014).

In various educational policy documents, the development of scientific inquiry has been viewed as an important goal in conjunction with scientific literacy, including the understanding of basic science concepts and the practice of scientific methods (Achieve, Inc., 2015; American Association for the Advancement of Science [AAAS], 1993; Lederman et al., 2014; NRC, 2000, 2011, 2013). Research emphasize that students' engagement with scientific inquiry processes motivate them to be physically as well as mentally active participants, help them acquire science and its significance in life, and assist them to develop competencies to function effectively especially in Science-Technology-Engineering and Mathematics (STEM) related careers (Bartos & Lederman, 2014; Gräber, 2012).

There are, however, such differences in definition of inquiry that eventually lead to tensions between the philosophical contemplations and how these are implemented in the classroom (Cavas, 2012; Treagust, 2014). For example, National Science Education Standards (NRC, 2000) differentiate between the abilities to do inquiry and having a fundamental understanding about specific characteristics of scientific inquiry (Lederman et al., 2014). The term inquiry refers to at least three distinct categories of activities as reported by Minner, Levy and Century (2010) (1) what scientists do methodologically, (2) how students learn through active participation, and (3) a pedagogical approach that teachers employ (Minner et al., 2010). Won (2010) reported that while in some cases, IBSE means a practice of "engaging students in interesting hands-on materials to teach scientific processes", in another case, IBSE was considered as "a collaborative group work as a means to build independence and democratic attitudes" (p.187).

In view of this uncertainty, the essential research aim was to set up an empirical-based common ground among different groups of stakeholders in Turkey about the aspects of science education, which are pedagogically desirable for the individual in the society of 21st century. In Turkey, the science education curriculum is motivated to reach ideal international standards of education implemented in Europe, North America and East Asia (Koc, Isiksal, & Bulut, 2007). Thus, Turkish science curriculum has representative particularities with the international context. Moreover, this study took place as part of a European project entitled Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science [PROFILES]. Therefore, the data collected in Turkey were shared with the European partners and the commonalities occurred in comparison to other partners were resulted with shared categories and concepts that were tested in consecutive rounds. Thus, the results of this research- although conducted in a national context- also reflect those shared categories and concepts in Europe, and so are a good initiative to discuss and understand the components of IBSE in international context that are most valued and pedagogically desired by different stakeholders.

Background

The philosophy of IBSE finds its antecedents in constructivist approaches to learning, claiming that IBSE was born out of the works of Jean Piaget, Lev Vygotsky, and David Ausubel (Alake-Tuenter, Biemans, Tobi, & Mulder, 2013; Cakir, 2008; Liang & Gabel, 2005; Minner et al., 2010). John Dewey, founder of the experiential learning pedagogy, puts the teaching of science through inquiry at the centre of his educational philosophy (Abd-El-Khalick et al., 2004).

In the 1960s, Joseph Schwab called for the teaching of science grounded on the idea of "inquiry into inquiry." (Abd-El-Khalick et al., 2004). Since then, the range of terms and phrases used to characterize the role of inquiry in science education are too widened to allow a clearly formulated philosophy about the nature of scientific inquiry to be implemented in science classrooms (Cavas, 2012; Abd-El-Khalick et al., 2004; Treagust, 2014). For example, in Europe, recent reports on science education emphasize IBSE as a key factor to be considered in science education (e.g. All European Academies [ALLEA] Working Group, 2012; Tucker, 2011). IBSE is defined in the Rocard report of the EC (2007) (p.108) as "the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, discussing with peers and forming coherent argument" (Linn, Davis, & Bell, 2004, p.4). The definition of inquiry in the ALLEA report covers the abilities similar to the process of scientific research and discovery.

In the USA, the policy documents (e.g. Benchmarks for Science Literacy (AAAS, 1993); Inquiry and The National Science Education Standards (NRC, 2000)) focuses on articulating how students can acquire science as a body of knowledge, a set of practices, and a process of participation in those practices (Furtak, Seidel, Iverson, & Briggs, 2012; Minner et al., 2010). For example, in the NGSS front matter, inquiry-based approaches to science teaching are described as those that "students will themselves engage in the practices and not merely learn about them secondhand" (NRC, 2013, p.11). The term "practices" is used in the document instead of inquiry or skills to emphasize that engaging in scientific inquiry comprises coordination of cognitive, social, and physical practices simultaneously. However, there is still confusion in science education community about the meaning of 'inquiry' and the methods to implement IBSE (Anderson, 2002; Dunne, 2013).

In Turkey, the curriculum was revised recently in 2013, and it has been implemented starting in primary schools in autumn 2013 and later in lower secondary and in upper secondary schools (MEB, 2013). In the science curriculum for grades 4-8, the formal and informal learning environments are suggested to be arranged based on the principles of IBSE indicated in the curriculum. The inquiry process is conceived not only as "discovery and experimentation", but also as "explanation and argumentation" process (p.III). Students are expected to construct strong arguments based on sound justification regarding natural and physical environment. Kizilaslan, Sozbilir, and Yasar (2012) reported that among the few studies conducted about IBSE as an educational approach in Turkey, the focus is mostly on the effect of IBL on learning some science topics. However, how IBSE could be effectively

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integrated into teaching science is still a mystery. As a consequence, the studies on the Turkish context indicate that IBSE is not widely used as a teaching and learning strategy in Turkey (Kizilaslan et al., 2012).

In overall, IBSE has been defined in policy documents mostly by the skills and abilities that aid students engage in science as a set of practices and a process of participation in those practices. For example, the documents refer to *diagnosing problems, formulating questions and hypotheses*, and *engage in scientifically oriented question* for identifying problem at hand, and suggest *discovery and experimentation* as well as *critiquing experiments* as activities and cognitive processes. The emphasis on *forming coherent arguments*, *arguing rationally, searching –often jointly with others- for evidence and accepting the confrontation of ideas*, and *seeking to reach conclusions, justify explanations* are common cognitive processes that students engage in during IBSE. Nevertheless, there are diverse ways to perform IBSE suggested in these documents. For example, one document might have students to plan investigations, research conjectures, search for information, and construct models about a scientific phenomenon, while another skips these steps and asks for epistemic practices such as connecting explanations to scientific knowledge, communicate and justify explanations, formulate explanations from evidence, give priority to evidence in response to questions, discussing with peers develop explanations and contrast this condition with students who also developed explanations distinguishing alternatives. These variations in the way that IBSE has been conceived lead to inconsistent inferences made in research syntheses about the effectiveness of the approach. A consequence of this diversity, as Abd-El-Khalick et al. (2004) correctly points out, is that the construct does not have its intended power "as an overarching theme for imagining, developing, coupling, and enacting curricular goals, pedagogical tools, and assessment practices that would allow the actualization of current reforms vision in science education" (p.414).

Therefore, the current move in science education is towards more detailed descriptions of IBSE in which the teacher and students engage rather than using the term as a one-for-all construct for educational reforms (Furtak et al., 2012). An important consideration in this regard is the need to establish an exchange between the different groups involved with the sciences and science education because innovative practices for science teaching incorporate socio-cultural considerations. Thus, involving various sets of stakeholders, who may hold divergent views, is a means to recognize these socio-cultural considerations and their influence on the image of science and the image of science in school (i.e. science education) held by students (as well as by their teachers and society). In this line, PROFILES project, which focuses on open inquiry approaches as a major teaching target, called for stakeholder involvement and interaction to fulfil this need to bridge the gap between science education research community, science teachers and local actors in order to facilitate the uptake of inquiry based teaching by supporting a stakeholder network and facilitating cooperation (PROFILES, 2010).

In response to this call, in this study, we aimed at illustrating views of stakeholders on desirable IBSE in the contradiction opinions of different selected communities from society in Turkey. The research was conducted by Curricular Delphi Study method, which offers comprehensive insights into the views of different stakeholders in society regarding how science education should be.

Research Questions

The central question of the PROFILES Curricular Delphi Study on Science Education is formulated as follows: "Which aspects of science education do you consider meaningful and pedagogically desirable for the individual in the society of today and in the near future?" The question is general to science education mainly because the term inquiry is not well-defined and all stakeholders might not – most were not-being familiar to the IBSE. For example, in Turkey, inquiry is generally known as research-inquire method of learning amongst educators; however, most of the people including students are either not familiar to the term or have different conceptions of inquiry.

Therefore, the research questions formulated in accordance with the research purpose are:

1. What are the preferred topics/themes and methods for teaching and learning science according to stakeholders' views?
2. Which characteristics of a desirable IBSE do the participants consider as being necessary and important for IBSE?
3. What differences or similarities appear in the general assessments between different sub-sample groups?

In regard to the differences expected in terms of the priority and practice of the components of inquiry-based science education as well as the differences expected between the sub-samples, the following hypotheses were formulated; H_1: There are significant differences between priority and practice assessments of the components of IBSE. H_2: The sub-sample groups are significantly different from each other in their assessments of priority and practice of the components of IBSE.

Methodology of Research

Delphi Method

Delphi method is a systematic approach to involving a wide range of stakeholders and bringing together their views (Linstone & Turoff, 1975). This method promises specific insights about aspects that are difficult to determine and to predict (Häder, 2009).

The PROFILES Curricular Delphi Study on Science Education is structured through three independent, yet interrelated rounds. The participating stakeholders are provided with feedback after each round regarding outcomes (Bolte, 2008; Bolte et al., 2012; Schulte & Bolte, 2012). In the first round, the participants' views about aspects of pedagogically desirable science education were collected according to question and answer format in 7 open-ended questions. In the second round, these categories were compared with those, which are reported by other partners in the PROFILES project; reorganized into statement bundles; and were reported back to the participants for further assessment. In the third round, the identified concepts were fed back to the participants for further assessment from two different perspectives analogously to the second round (Schulte & Bolte, 2014).

Sample of the Research

In the first round of the Delphi study, in total, the number of stakeholders involved in Turkey was 135. The stakeholders were selected by convenient sampling, in which the stakeholders were the ones that were accessible and volunteered to contribute to the study. The only selection criterion was that the stakeholder must be a member of one of the groups (scientists, science teachers, science teacher educators, education administrators, and students) that were identified through a consensus by project partners. Out of 134 (79 male; 55 female) participants from the first round, a total number of 125 (79 male; 46 female) participants (93% of the participants from the first round) took part in the second round. The participation rate in the second round for the groups compared to the first round participation were high (93%-100%), with the exception of scientists and other (71%). Table 1 shows the sample structure over all three rounds of the study. Also, the participation rate with regard to the drop-out between the second and third round is shown.

With regard to the second round, all the sub-sample groups feature with 100% or higher response rate in the third round, with the exception of education administrators (70%). Hence, there were 125 participants who took part in all of the three rounds of the study. The refinement of the stakeholders' views as well as reaching to a consensus on the critical goals of the science education is important first, in developing the practices, ideas, intentions and objectives to facilitate the uptake of innovative science teaching and the enhancement of scientific literacy and second in allowing a stronger partnership between various stakeholders and science teachers.

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Table 1. Sample structure.

		Number of participants		
	Sample group	Round 1	Round 2	Round 3
Students		29 (12f; 17 m)	29(12f; 17 m)	29(12f; 17 m)
Teachers	Education Students	25(15f; 10 m)	30(15f; 15 m)	25(15f; 10 m)
Teachers	Trainee teachers & Teachers	25(15f; 10 m)	16 (15f; 11 m)	21(14f; 7 m)
Teachers	Teacher Educators	26(19f; 7 m)	25 (19f; 6 m)	25 (19f; 6 m)
Education Administrators		9 (8f; 1 m)	10 (8f; 2 m)	7 (5f; 2 m)
Scientists and Other		21(11f; 10 m)	15(10f; 5 m)	18 (10f; 8m)
	Total	135(80f; 55 m)	125(79f; 46 m)	125(75f; 50 m)

Therefore, the data in the 3rd round were collected from students (19 elementary school (8th grade)- 10 high school (10th grade)); pre-service (5 biology, 3 chemistry, 5 physics, 12 elementary science) and in-service teachers (21 science teachers with 1 to 20 years of experience); teacher educators (25-from different universities), education administrators (2 program developers, 2 education politicians, 3 administers from ministry of education) , scientists (5 biologist, 5 physicist, 5 chemists), and others (3 engineers who are also employers in industry).

Design of the Questionnaires and Data Collection

1st round

The questionnaire used in the first round of the research was adapted by collaboration with other partners included in the PROFILES project. The questionnaire consists of 7 questions (Appendix). The questions addressed the following areas:

- Preferred topics/themes and methods for teaching and learning science (question 1)
- Skills and attitudes that should be encouraged in school science (questions 2, 5, 6)
- Suggestions for improving science education/scientific literacy of individuals (questions 3, 4, 7)

Scientific literacy is a complex construct (DeBoer, 2000), so its enhancement would not be possible by referring to the different aspects one by one. Therefore, the questionnaire was open-ended and sought for stakeholders view without giving clue of what IBSE should be. Thus, in the first round of the research, in order to picture responses, aspects were constructed following the results from other partners in the project and refer to guidelines and aspects of modern science education stated in didactic literature (Bybee, McCrae, & Laurie, 2009; Fensham, 2009; Häußler et al., 1980). In other words, we could not define and ask what the stakeholders think inquiry-based science education is. However, the stakeholders' responses were compared with the IBSE conceptualization in the policy documents, PROFILES model, as well as research on IBSE. It was important that our views do not impinge on participants' responses. Therefore, little guidance was given as to the expected content of responses in the first round of the Delphi study.

2nd round

The second round of the PROFILES Curricular Delphi Study on Science Education is about critically considering and reflecting the findings which resulted from the analyses of the individually formulated responses of the participants in the first round. Thus, the categorisation resulted at the end of the comparisons of first round among PROFILES partners is fed back to the participants and combined with specific tasks and questions. The second round also helps to identify empirically based conceptualization with regard to the stakeholders' desired and perceived models of science education since the stakeholders picture what is important and relevant for science education in this round.

3rd round

The concepts of desirable science education that were identified in the second part of the second round were reported back to all the participants in the third round for their assessment. The concepts were assessed from two points of view ("priority" and "practice") on a six-tier scale. We followed a structured model to make sure that obtained data is comparable. Since this research was EU project, the experts' reviews from 19 different EU countries have been taken into consideration in each country and then final version of questionnaire was implemented in Turkey and each partner countries as well. The objectivity, reliability and validity of the instruments have been checked by the experts of science educators, too.

Data Analysis

Since the Delphi questionnaire used in the first round of the research is composed of open-ended questions, a qualitative approach to data analysis was preferred. The statements were analysed step-by-step as indicated in the model described by Schulte and Bolte (2012). Consequently, the results of the data gathered involved codes and categories drawn in an interpretive nature by the researchers involved in the study.

For the assessment of the categories, the data from 2nd and 3rd round questionnaires were analysed by descriptive and variance analytical methods. The analyses took into account both the priority and practice assessments individually as well as determined the priority-practice differences by subtracting the practice values from the priority values (Bolte, 2008). The analyses were made from two perspectives: general assessment of the concepts of science education by the total sample and by the sub-sample groups. The assessments of the concepts were tested for statistically significant differences by applying the Wilcoxon signed-rank test. Statistically significant differences between the assessments of the different sub-sample groups were identified through the Mann-Whitney-U test.

Results of Research

1st Round

In the first round of the research, the participants expressed their views with regard to the pedagogically desirable science education in 7 questions in total. The qualitative analysis of the statements led to a classification system consisting of 5 parts. The second part was subdivided onto two parts (IIa and IIb). All in all, it contains a number of 157 categories.

The codes (Table 2) were agreed with 97% interrater reliability and the ones for those we had a conflict were either discussed further to reach an agreement or removed completely. Initial categories were determined in a meeting where three researchers from the project team in Turkey participated, and adjusted later when we contributed to the internationally agreed list of categories. In addition to the categories identified in the analysis of the first round data and as a result of the international comparisons, the results obtained in the first round in Turkey yielded one more category, which is Learning Environments (Table 2). This category is highly emphasized as a major element of learning in science classrooms by the respondents in Turkey.

Learning environments describe the contexts where science learning takes place and suggested to be effective. A total number of 1203 statements was determined. In overall, Table 3 represents the most and the least emphasized keywords by different participants regarding each question. Additionally, as a response to *question 3; is there anything you would like to see change in school science lessons,* participants proposed alterations in school-science from various perspectives.

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Table 2. Overview of the categories for the analysis of the experts' statements.

I: Situations, contexts, motives N=19	II: Fields		III:	IV: Methodical aspects N=25	V: Learning environments N=24
	IIa: (Basic) concepts and topics N=37	IIb: Scientific fields and perspectives N=10	Qualification N=42		
Daily life	Laws, theories,	Physics	Science	Entrepreneurship	laboratory
related	facts	Biology	process skills	Obtaining result	visual
knowledge	Scientific	Chemistry	knowledge	Explaining	book
Knowledge	developments	Technology	application	Discussing	material
based on	Exam topics	Geology	critical	Collaboration	field
curricula	theoretical	History of	thinking skills	Planning	equipment
Science society	content	Science	knowledge	experiment	technological
technology	current	Astronomy	transfer	process learning	audio
issues	technology	Philosophy	positive	practice	resource
daily life	philosophy	of science…	attitude	Search…	Instrument…
occurrences	scientists		problem		
Technological	Future		solving		
developments…	profession…		Cognitive		
			skills…		

The participants emphasized curriculum-based changes, student-related changes, context-based changes, teacher-related changes, and policy-related changes. For example, a pre-service teacher responded that;

> "I don't think that the curriculum has been implemented with a constructivist approach in schools as intended. The main two reasons are the inadequacy of teachers in constructivist methods, and the lack of technical supply in classrooms. Indeed, the science teaching in schools does not allow students to be active participants."

The pre-service teacher in this example emphasized teacher's role in the implementation of the curriculum and recommended *teacher-related changes*. At the same time, s/he talked about the learning environment, and suggested the *context* to be more student-centred.

The participants gave examples from diverse areas when they are asked to describe a situation, context or topic where they think scientific literacy is useful. The participants highlighted the daily-life occurrences (12.6%) as the area where scientific literacy is the most needed. Although they mentioned about scientific content (0.7%), this area of knowledge remained insignificant among the other areas, which are mostly socio-scientific. For example, a scientist responded that;

> "Scientific literacy is helpful to critically think about the situations that would have an impact on our life. For example, a scientifically literate person should be able to think critically and make an informed decision about the effects of nuclear or hydroelectric power plants on environment, human life, and economy."

This response emphasized the importance of having an adequate scientific literacy in socio-scientific decision-making.

Table 3. Overview of the categories for the analysis of the experts' statements.

		Keywords	n	n%	Teacher %	Student %	Teacher educator %	Scientist %	Education administer %
Question 1- significant area or field of science	Top	Physics	69	51.1	58	38	27	86	44
		Biology	63	46.7	54	21	35	81	44
		Chemistry	62	45.9	46	59	31	48	44
	Bottom	Philosophy of science	1	0.7	0	3	0	0	0
		Science related knowledge	1	0.7	0	3	0	0	0
		Nature of Science	1	0.7	0	0	4	0	0
Question 2- significant competencies	Top	knowledge application	49	36	18	38	27	38	44
		science process skills	40	30	30	21	35	33	44
		critical thinking skills	32	24	30	59	31	29	44
	Bottom	the use of technology	3	2	2	0	8	0	11
		scientific thinking	1	1	2	7	4	0	0
		scientific literacy	1	1	2	3	4	0	11
Question 5- scientific literacy skills	Top	Understanding	24	18	22	38	27	29	44
		Thinking	22	16	22	21	35	5	44
		Knowing	14	10	12	59	31	10	44
	Bottom	Nature of science	5	4	6	0	0	0	11
		Science and society	5	4	8	3	0	0	0
		Consistency	1	1	2	3	0	0	0
Question 6- scientific literacy attitudes	Top	Curiosity	28	21	28	38	27	14	44
		Interest	22	16	8	21	35	10	44
		Technology	18	13	6	59	31	10	44
	Bottom	Guidance	2	1	0	0	4	0	0
		Motivation	2	1	0	0	4	0	0
		Collaboration	8	6	2	0	4	14	0
Question 7- suggestions	Top	curriculum issues	46	34	36	38	27	38	44
		scientific activities	34	25	16	21	35	38	44
		linking daily life	26	19	24	59	31	14	44
	Bottom	scientific process skills	9	7	6	7	4	14	0
		financial support	6	4	2	3	4	5	11
		early science education	5	4	6	0	0	0	11

To find answers to the guiding questions of the second round, we calculated the descriptive statistics (mean, standard deviation, n) regarding the priority-assessment differentiated according to the groups of students, teachers, educators, scientists and adults (including the groups of teachers, educators and scientists).

2nd Round

Table 4 shows those categories that feature particularly high or particularly low mean values with regard to the total sample, listing the top three and bottom three categories in descending order. In the table, considering the top categories, it can be noted that they refer to aspects rather related to qualifications and learning environments. Although it is not seen in the table, overall results also show that almost half of the (41 out of 76) categories range above the theoretical mean value (4.9) of the scale.

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Table 4. Top and bottom three categories of the assessments by the total sample.

		Category	Mean Value
Priority Assessments	Top	Laboratory work	5.4
		Problem solving/Critical questioning	5.3
		Making decisions /opinion-forming / reflection	5.3
	Bottom	Intellectual development	4.4
		Subject content focussed learning	4.3
		Media / current issues in society	4.3
Practice Assessments	Top	Learning related to Science - biology	4.4
		Subject content focussed learning	4.4
		Learning related to Science - chemistry	4.4
	Bottom	Intellectual development	3.2
		History of sciences	3.2
		School areas for animal/ plant growth	3.0
PPD Assessments	Top	School areas for animal/ plant growth	1.9
		Rational thinking / analysing / drawing conclusions	1.8
		Making decisions /opinion-forming / reflection	1.8
	Bottom	Matter / particle concept	0.4
		Chemical changes/reactions	0.4
		Subject content focussed learning	-0.1

The PPD results from subtracting the practice values from the priority values ($\Delta PPD = X_{priority} - X_{practice}$). A notable finding is that the PPD of the category "Subject content focussed learning" features a negative value (-0.1). This indicates that in the opinion of the participants, the presence of this aspect in science educational practice exceeds the importance the participants attribute to this aspect. The comparison of the mean values of the different sample groups and the values of the significance test (Mann-Whitney-U-Test) regarding the comparisons of the mean values in different sample groups showed a tendency towards slightly higher values in the responses of the 'adult' groups (Table 5).

Table 5. Significance values and mean values of the assessments by the different sample groups and the total sample.

		Number of Significance & values						Average Mean values				
Categories		S/T	S/E	S/Sc	T/E	T/Sc	E/Sc	S	T	E	Sc	Total
I: contexts, motives and situations	priority	5 p <.03	3	0	1 p= .00	1 p= .04	1 p= .01	4.41	5.01	5.13	4.76	4.83
	practice	6 p=.00	1 p=.00	5 p <.05	0	0	1 p=.04	4.43	3.70	3.88	3.55	3.89
	PPD	9 p=.00	8 p=.00	9 p <.03	0	2 p <.04	3 p <.05	0.37	1.11	1.29	1.24	1.01
II: concepts and topics	priority	6 p <.03	2 p <.01	2 p=.01	1 p= .04	2 p <.04	1 p= .05	4.53	5.15	5.04	4.88	4.90
	practice	11 p=.00	6 p=.00	12 p <.05	0	2 p <.04	0	4.30	3.66	3.38	3.16	3.63
	PPD	18 p=.00	15 p=.00	12 p <.05	0	2 p <.04	1 p=.02	0.29	1.23	1.39	1.53	1.11

		Number of Significance & values						Average Mean values				
III: qualifications	priority	6 p <.01	1 p=.02	3 p <.03	0	2 p <.04	0	4.69	5.38	5.09	5.25	5.10
	practice	11 p=.00	13 p=.00	9 p <.03	0	0	1 p=.04	4.30	3.55	2.99	3.34	3.54
	PPD	15 p=.00	14 p=.00	12 p <.02	0	1 p=.04	0	0.51	1.70	2.08	1.98	1.57
IV: methodological aspects	priority	3 p <.01	0	1 p=.04	1 p=.04	0	0	4.84	4.97	4.66	5.14	4.91
	practice	9 p=.00	11 p=.00	7 p <.05	8 p=.00	0	5 p <.05	4.34	3.58	2.64	3.50	3.52
	PPD	11 p=.00	11 p=.00	8 p <.03	0	1 p=.01	0	0.48	1.30	1.90	1.66	1.33
V: learning environments	priority	4 p <.02	1 p=.02	3 p <.03	1 p=.01	2 p <.05	0	4.60	5.19	4.89	4.87	4.89
	practice	4 p=.00	5 p=.00	3 p <.03	0	1 p=.05	0	4.15	5.19	4.89	4.87	4.89
	PPD	6 p=.00	5 p=.00	3 p <.03	0	1 p=.03	0	0.44	1.96	1.74	1.60	1.43

The highest number of statistically significant differences (p=.05) in the assessments appears in the comparison between the responses of the students and teachers. In detail, in the priority assessment, 24 statistically significant differences in each pair comparison, accounting each for 45% of all cases in the respective pair comparison were found.

In the practice assessments, there were 41 statistically significant differences in each pair comparison, accounting each for 31% of all cases in the respective pair comparison. In priority-practice differences (PPD), the highest number of statistically significant differences in the practice assessments was 59 statistically significant differences in each pair comparison, accounting each for 35% of all cases in the respective pair comparison.

All in all, a number of 53 statistically significant differences can be found with regard to the priority assessments; 131 statistically significant differences can be found with regard to the practice assessments; and 167 statistically significant differences can be found with regard to the PPD assessments. On the other hand, it is hard to say that the groups significantly differ from each other without controlling the threats to multiple comparisons problem.

3rd Round

In the third round, the data of the second round from all partners in the project were gathered together and analysed by means of hierarchical cluster analyses, using the Ward method and squared Euclidian distance (see Bolte & Schulte, 2013) by the coordinator institution of the project first to refine the understanding of IBSE among partner countries, and second to allow group comparisons. As a result of this analysis, the categories were collapsed into three concepts of science education; Concept A, which is *Awareness of the sciences in current, social, globally relevant and occupational contexts in both educational and out-of-school settings*, Concept B, which is *Intellectual education in interdisciplinary scientific contexts* and Concept C, which is *General science-related education and facilitation of interest in contexts of nature, everyday life and living environment* (Appendix).

In regard to the general assessment of the three concepts of science education by the total sample, it can be said that the concept referring to general science-related education (Concept C) is seen as the most important and also most realized concept of the three concepts. However, the priority-practice differences show that in the current science education practices all three concepts fall short of their given priority. The smallest gap occurs for the awareness of the sciences in different contexts (Concept A), the largest for the concept related to intellectual education related concept (Concept B).

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In the following part, the general assessments by the different sub-sample groups are presented. Table 6 shows the results of these assessments and the results from the significance test with respect to differences between the assessments of the different concepts (Wilcoxon signed-rank test).

Table 6. Mean values of the general assessments by the sub-sample groups and significance test values.

		Mean values				Significance values		
		Concept A	Concept B	Concept C	Average	A/B	A/C	B/C
Priority	Students (S)	5.62	5.69	5.90	5.74	0.589	0.011	0.063
	Teachers (T)	5.39	5.15	5.69	5.41	0.087	0.002	0.000
	Ed. Adm.'s (A)	4.70	5.20	5.30	5.07	0.059	0.084	0.705
	Scientists (Sc)	5.13	5.27	5.67	5.36	0.608	0.033	0.177
Practice	S	4.72	4.62	4.83	4.72	0.693	0.750	0.210
	T	3.56	3.31	3.87	3.58	0.096	0.033	0.001
	A	3.10	2.70	3.20	3.00	0.157	0.739	0.025
	Sc	3.40	3.20	3.60	3.40	0.405	0.490	0.153
PPD	S	0.90	1.07	1.07	1.01	0.448	0.602	0.971
	T	1.83	1.85	1.82	1.83	0.918	0.934	0.791
	A	1.60	2.50	2.10	2.07	0.038	0.334	0.157
	Sc	1.73	2.07	2.07	1.96	0.096	0.218	0.875

Table 7 shows in addition the results from the significance test with respect to differences between the assessments by the different sub-sample groups (Mann-Whitney-U-Test).

Table 7. Mean values of the assessments by the sub-sample groups and significance test values.

		Significance values						Mean values				
	Concepts	S/T	S/E	S/Sc	T/E	T/Sc	E/Sc	S	T	E	Sc	Total
Priority	Concept A	0.046	0.010	0.018	0.052	0.163	0.428	5.62	5.39	4.70	5.13	5.21
	Concept B:	0.001	0.162	0.031	0.416	0.747	0.693	5.69	5.15	5.20	5.27	5.33
	Concept C:	0.067	0.106	0.149	0.612	0.965	0.699	5.90	5.69	5.30	5.67	5.64
Practice	Concept A:	0.000	0.003	0.003	0.464	0.756	0.723	4.72	3.56	3.10	3.40	3.70
	Concept B:	0.000	0.001	0.005	0.147	0.518	0.511	4.62	3.31	2.70	3.20	3.46
	Concept C:	0.003	0.004	0.005	0.198	0.535	0.452	4.83	3.87	3.20	3.60	3.88
PPD	Concept A:	0.002	0.111	0.028	0.626	0.870	0.817	0.90	1.83	1.60	1.73	1.52
	Concept B:	0.012	0.014	0.025	0.160	0.552	0.493	1.07	1.85	2.50	2.07	1.87
	Concept C:	0.017	0.093	0.017	0.585	0.498	0.910	1.07	1.82	2.10	2.07	1.77

Similar to the result of the assessments by the total sample, it can be noted for the sub-sample groups as well that all assessments range above the theoretical mean values of 3.5. As the average of the mean values for the three concepts shows, the teachers, education administrators and scientists feature for the three concepts a tendency towards higher priority assessments. With respect to the practice assessments by different sub-sample groups, it is noticeable for all three concepts that the group of education administrators deviate to rather lower values, whereas the group of students seems to assess the realization in a more positive way. The assessments of the sub-sample groups feature no mean value above the theoretical mean value of 3.5, except the group of students.

For all three concepts, the smallest gaps between the priority and practice assessments appear in the group of students. The largest gaps between priority and practice assessments appear both in the group of education researchers and scientists. The largest gap between priority and practice in the assessments of the students appears for Concept B and Concept C. In the assessments of the three other sub-sample groups, the largest gaps appear for Concept B.

All in all, the four sub-sample groups seem to be very homogeneous in their assessments of the realization of the three concepts. However, the assessments made within the sub-sample groups in the PPD assessments are very similar. Statistically significant differences appear between Concept A/ Concept B (education researchers).

Discussion

The first questionnaire provided the stakeholders' conceptualizations of the pedagogically desirable science education. The conceptualizations were further refined in the 2nd and 3rd round to understand the specific attributions made to the inquiry-based science education by stakeholders.

In the second and third rounds, care was taken to ensure, as far as possible, that participants' own words were returned and that participants had ample opportunity to comment on any interpretation in our conflation of their responses. As a result, the analyses show general tendencies as well as specific focuses of the participants and the different groups of participants. The category frequency regarding the whole sample showed that 13 categories were mentioned particularly often (by 20% or more than 20% of the participants) while 100 categories were mentioned particularly rarely (by 5% or less than 5% of the participants). The numbers show the huge diversity of views expressed by the stakeholders.

As similar to other curricular Delphi studies in the science education (Bolte, 2008; Häußler et al., 1980; Mayer, 1992; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003), the PROFILES Curricular Delphi Study is divided into three rounds. In the first round, differentiated analyses according to the sample groups showed that, all stakeholders emphasize the role of science education in the survival of a country. They all put a great emphasis on the curriculum, but the topics they suggest to include in the curriculum do not show a noteworthy differentiation from the current curriculum. The problems with teacher training and integration of nature of science are stayed in the backstage in this manner. As expected, the group of teacher educators responded in the most differentiated way (137 categories), followed by the group of teachers (119 categories). As these groups are those who research, read and interact with the educational resources the most, the diversity in their views can be considered as a reflection of the extent of their involvement in educational matters as an essential part of their profession.

From the stakeholders' perspective, the results show resemblance to the current consensus of the science education community on the definition, aspects and the role of inquiry-based instruction in science. However, the significance of the results of this curricular Delphi study on science education lie in the prioritization and the realization of these categories in the views of students, teachers, educational administrators, and scientists. In this regard, the analyses of the second and third round provide important suggestions for the goals, content and qualifications of IBSE. Furthermore, these outcomes, which clarify the meaning of IBSE as it has been hold by different stakeholder, make it useful by adapting the views into the development of teaching and learning modules, as well as for teacher training strategies and materials (Schulte & Bolte, 2012). For example, in Turkey, based on the results of the study, workshops with more than 40 science and technology teachers, who teach at elementary schools (grades 6-8) were held and empirical-based teaching modules for IBSE were constructed (Ozdem & Cavas, 2012).

The assessments made by the stakeholders represent evidence to the significance of engagement with the interdisciplinary relations of the sciences, their findings and their perspectives with regard to their role in enhancing individual intellectual personality development. Furthermore, the stakeholders' views suggest that dealing with the IBSE not only serve the acquisition of science-related basic knowledge but more than this; it also helps to the process of applying knowledge in the sciences in interdisciplinary contexts by means of facilitating analytical abilities; such as, creative and abstract thinking, critical questioning, rational thinking, analysing, drawing conclusions, and fostering the ability to take differentiated perspectives. In other words, scientific inquiry

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is not only related only to the widely known science processes, but it includes the ability to consolidate these processes with scientific knowledge, scientific reasoning and critical thinking to advance scientific knowledge (Lederman & Lederman, 2012). Whereas, the stakeholders put emphasis on the significance of these aspects of inquiry-based science education, the science education policies rarely give specific attention to this role of IBSE. As a result, the research notes to students' positive engagement with and success in the inquiry processes such as setting up meaningful experiments, but also to the limitations in students' understanding of data, as well as the relationships among data, evidence, and conclusions (Keys, 1998; Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998).

Conclusion and Implications

The aspects of science education, which are pedagogically desirable for the individual in the society of 21st century and investigated in this research, were found to be mostly consistent with the contemporary science education policies. The list of pedagogically desirable concepts, qualifications and contexts points out to a future, which is technology dominated and risky in all means. Since nobody is able to imagine what the future will be like except being highly technological, the worries about safety, health, and being ethical and independent take over in the responses of the stakeholders. In conclusion, this research set forth the need to revise the science education policies and the curricula to adapt the forthcoming technological advances especially in the areas of health and environment, and their unpredictable consequences.

In this research, we have presented a research methodology to collect vital data on how different stakeholders view pedagogically desirable inquiry-based science education. The findings of this study are significant to inform the science education community, educational administrators, teacher educators, and the public about the goals, contexts, perspectives and qualifications of inquiry-based science education that has been already carried out in science classrooms in order to close the gap between the one pedagogically desired from the perspective of diverse participants. We propose that only then the expected student learning outcomes from IBSE can be reasonably proposed in the policy documents as the reflection of multiple modes of pedagogically desirable inquiry-based science education. It is suggested that this information is going to be valuable in further evaluation of the efficacy of inquiry-based science education as a teaching and learning strategy in science.

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Appendix

The questionnaire used in the 1st round of Delphi study

1. Which area or field of science do you think is significant that a secondary school graduate should know?
2. What competencies do you think school science should encourage/develop?
3. Is there any change that you would like to see in school science lessons?
4. Describe a situation or context or topic where you think scientific literacy is useful.
5. List the skills you think someone who is scientifically literate should have.
6. List the attitudes you think someone who is scientifically literate should have.
7. What do you think would improve the development of scientific literacy?

Description of the concepts

	Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts in both educational and out-of- school settings	**Concept B: Intellectual education in interdisciplinary scientific contexts**	**Concept C: General science- related education and facilitation of interest in contexts of nature, everyday life and living environment**
Situations, contexts, motives:	Emotional personality development, Media / current issues, Global references, Occupation / career, Out of school learning, Curriculum framework	Intellectual personality development, Science - interdisciplinary, Technology	Society / public concerns, Students' interests, Education / general personality development, Nature / natural phenomena, Everyday life, Medicine

	Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts in both educational and out-of- school settings	**Concept B: Intellectual education in interdisciplinary scientific contexts**	**Concept C: General science- related education and facilitation of interest in contexts of nature, everyday life and living environment**
(Basic) concepts, themes and perspectives:	History of the sciences, Occupations / occupational fields, Industrial processes, Cycle of matter, Earth sciences, Development / growth	Interdisciplinary, Scientific inquiry, Current scientific research, Limits of scientific knowledge, Terminology, Matter / particle concept, Structure / function / properties, Chemical reactions, Models, Technical devices, System, Interaction, Energy, Mathematics	Safety and risks, Consequences of technological developments, Ethics / values, Food / nutrition, Health, Matter in everyday life, Environment
Qualifications:	Empathy / sensibility, Perception / awareness / observation, Social skills / teamwork, Knowledge about science-related occupations, Communication skills, Finding information, Reading comprehension	Applying knowledge / creative and abstract thinking, Formulating scientific questions / hypotheses, Factual knowledge, Critical questioning, Rational thinking / analysing / drawing conclusions, Experimenting	Acting reflectively and responsibly, Judgement / opinion-forming / reflection, Motivation and interest, Comprehension / understanding, working self-dependently / structured / precisely.

Samples question from the 2nd round questionnaire seeking opinions on science education priorities and current practices

Situations, contexts and motives Please assess the following categories according to the two questions stated.	Which priority should the respective aspects have in science education?						To what extent are the respective aspects realized in current science lessons?					
	1= very low priority 2= low priority 3= rather low priority 4= rather high priority 5= high priority 6= very high priority						1 = to a very low extent 2 = to a low extent 3 = to a rather low extent 4 = to a rather high extent 5 = to a high extent 6= to a very high extent					
Intellectual development	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]
Development of the Person	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]
The interests of Students	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]

Samples question from the 3rd round questionnaire seeking opinions on science education priorities and current practices

Concepts Please assess the following categories according to the two questions stated.	Which priority should the respective aspects have in science education?						To what extent are the respective aspects realized in current science lessons?					
	1= very low priority 2= low priority 3= rather low priority 4= rather high priority 5= high priority 6= very high priority						1 = to a very low extent 2 = to a low extent 3 = to a rather low extent 4 = to a rather high extent 5 = to a high extent 6= to a very high extent					
Concept A: Awareness of the sciences in current, social, globally relevant and occupational contexts in both educational and out-of-school settings	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]
Concept B: Intellectual education in interdisciplinary scientific contexts	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]
Concept C: General science-related education and facilitation of interest in contexts of nature, everyday life and living environment	[1]	[2]	[3]	[4]	[5]	[6]	[1]	[2]	[3]	[4]	[5]	[6]

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