SCIENCE TEACHERS AS KEY ACTORS IN RESPONSIBLE RESEARCH AND INNOVATION: EVALUATION OF A TEACHER TRAINING PROGRAM

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ABSTRACT

This work presents the design and evaluation of a teacher professional development (TPD) program intended to promoting responsible research and innovation (RRI) through science education. The training course, builds on teachers' beliefs, provides opportunities to experience the educational potential of the innovative approach, makes explicit links to the science curriculum and supports the development of specific teaching skills necessary to enact the underpinning science education model. Additionally, we present the validation of instruments to evaluate the impact of the TPD program on teachers' beliefs. The analysis of pre-post results shows a positive evolution of participants' beliefs in line with the science education model being promoted.

KEY WORDS

Responsible Research and Innovation (RRI), Teacher Professional Development, Science Education, Questionnaire, Validation of instruments.

SISYPHUS
JOURNAL OF EDUCATION
VOLUME 5, ISSUE 03,
2017, PP.107-121

Os Professores de Ciências Como Atores-chave em Investigação e Inovação Responsáveis: Avaliação de um Programa de Formação de Professores

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RESUMO

Este trabalho apresenta a conceção e avaliação de um programa de desenvolvimento profissional de professores (DPP) destinado a promover a Inovação e Investigação Responsáveis (IIR) através da educação em ciências. O curso de formação baseado nas crenças dos professores proporciona oportunidades para experienciar o potencial educacional da nova abordagem, produz ligações explícitas com o currículo de ciências e fundamenta o desenvolvimento de capacidades específicas de ensino necessárias para determinar o modelo subjacente da educação em ciências. Além disso, apresentamos o modelo de validação dos instrumentos de avaliação do impacto do programa de desenvolvimento profissional nas crenças dos professores. A análise dos resultados pré-publicados mostra uma evolução positiva das crenças dos participantes em linha com o modelo da educação em ciências que está a ser utilizado.

PALAVRAS-CHAVE

Investigação e Inovação Responsáveis (IIR), Desenvolvimento Profissional dos Professores (DPP), Educação em Ciências, Questionário, Validação de Instrumentos.

SISYPHUS
JOURNAL OF EDUCATION
VOLUME 5, ISSUE 03,
2017, PP.107-121

Science Teachers as Key Actors in Responsible Research and Innovation: Evaluation of a Teacher Training Program

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INTRODUCTION AND BACKGROUND

Responsible Research and Innovation (RRI) is defined as "a process where societal actors work together, via inclusive participatory approaches, during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society" (European Commission, 2015, p. 69). For effective participation in RRI, citizens need to be scientifically literate, i.e., having a critical understanding of the processes and products of science and technology and being able to deal with the associated socio-scientific issues (OECD, 2016).

In order to address the abovementioned challenges science teachers play a key role. Nevertheless, a model of science education mainly based on the explanation of scientific facts, laws and theories may not be enough to educate scientifically literate citizens (Ariza, Quesada, Abril & García, 2016). Therefore, it is necessary to support teachers in adapting their classroom practices, in order to better respond to these educational demands. But, what kinds of pedagogies support the efficient achievement of these learning outcomes? Inquiry-Based Learning (IBL), Socio-Scientific Issues (SSI), and Citizen Education (CE) are different educational approaches that have been advocated by experts and different political documents as means to address current challenges in science education (European Commission, 2007, 2015; Sadler & Dawson, 2012). The European project PARRISE (Promoting Attainment of Responsible Research and Innovation in Science Education) has successfully developed a model for science education which integrates these four components (http://www.parrise.eu). PARRISE is an international project funded within the Seven Framework Program by the European Union, which involves 18 institutions from different European countries. The main goal is to develop a research-based model for supporting teachers to promote RRI through science education. The model developed is called Socio Scientific Inquiry Based Learning (SSIBL) and has been described and discussed somewhere else (Levinson & the PARRISE consortium, 2017). Starting from an RRI context and making links to powerful socio-scientific scenarios, the SSIBL model empower teachers to work with students in the map of the controversy and in the development of democratic informed opinions, which should lead to responsible and responsive actions (Romero-Ariza, Abril & Quesada, 2017).

Supporting teachers to uptake SSIBL is a challenging endeavor, which requires adequate programs for teacher initial education and continuous professional development consistent with the methodological changes being promoted.

Taking into account the above-mention background, the objectives of the present work are:

1. To present a research-based model of teacher professional development (TPD) to promote scientific literacy and RRI though science education.
2. To discuss the process of development and validation of some instruments to measure teachers' beliefs about how science education should be taught and learnt and the science education model being promoted.
3. To evaluate the impact on teachers' beliefs of a TPD program for promoting RRI through science education.

A RESEARCH-BASED PROGRAM FOR TEACHER TRAINING

In the following we draw on the specialised literature about teacher professional development in order to determine what makes a teacher training program effective in terms of its impact on teaching practices. The main goal is to provide a research basis for the design of a program intended at equipping teachers with the knowledge, skills and dispositions necessary to promote RRI through science education.

Teacher beliefs are known to play a key role not only on teaching practices, but also on teachers' acceptability of innovation and potential change (Basturkmen, 2012; Buehl & Beck, 2015; Donnell & Gettinger, 2015; Glackin, 2016; Herrington, Bancroft, Edwards & Schairer, 2016; Hofer, 2006; Lebak, 2015; Wong & Luft, 2015).

Trying to unpack the complex relationship between beliefs, practices and change, Leback (2015) shows that initially espoused beliefs were often inconsistent with enacted practice and some beliefs emerged as more salient than others for influencing practice. The analysis indicates that change in both beliefs and practice was an interactive process mediated by collaborative and self-reflection through teachers' active participation in the process (Leback, 2015).

Along with needs to take into account teachers' previous beliefs and experiences, the review conducted by Luft and Hewson (2014) highlights other key components of effective teacher professional development. These authors emphasize the importance of providing long-term support, linking innovation with science curricula and focussing on both, science content knowledge and pedagogical content knowledge. The use of specialised techniques for teacher professional development and the promotion of specific teaching competences are also highly recommended (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003).

Based on the above research results, we have designed a program for teacher professional development that builds on teachers' beliefs, makes explicit links to science curricula, focus both on science knowledge and pedagogical content knowledge, implements specific techniques for teacher professional development and provides multiple opportunities for communication, collaboration and reflection (Ariza, Quesada, Abril & García, 2016; Loucks-Horsley et al., 2003; Luft & Hewson, 2014; Penuel, Fishman, Yamaguchi & Gallagher, 2007).

As previously mentioned, the ultimate goal of the designed TPD program is supporting teachers in the education of future citizens able to actively participate in RRI. The program encompasses a set of successive TPD activities articulated in seven phases, which place teachers into different roles: teachers as learners, teachers as designers and teachers as reflective practitioners:

Phase 1: Building on teachers' beliefs and concerns
The main goal of this initial phase is to provide teachers with opportunities to express their beliefs on science teaching and learning. This activity promotes teachers' engagement and allows educators to identify teachers' epistemic beliefs and build on them to enhance impact on teaching practices.

Phase 2: Highlighting links with the Spanish curriculum
The initial activity to make participants' beliefs explicit is followed by an open discussion on current challenges in science education related to the promotion of students' competences, critical thinking and scientific literacy. Teachers are encouraged to identify those learning outcomes within the Spanish policy documents; afterwards, they will be given the opportunity to reflect on how the SSIBL model can assist them in bringing about these learning outcomes.

Phase 3: Experiencing the educational potential of SSIBL as learners
In this phase teachers are encouraged to inquiry on a trendy socio-scientific issue in order to make informed-decisions. In the process they will really experience the SSIBL approach as students.

Phase 4: Reflecting on students' learning through SSIBL
After experiencing SSIBL as learners, teachers are asked to reflect on what their students could learn through these kinds of activities. Additionally, they are invited to identify links between the potential learning outcomes from SSIBL activities and curricular recommendations for science education.

Phase 5: Developing specific teaching skills
The enactment of the SSIBL model requires an important change in the classroom culture. Teachers will need to successfully engage students and support them to productively inquire about relevant socio-scientific issues and promote reasoning, deliberation and informed decision-making. Thus, our program includes activities to develop specific teaching skills related to the identification and design of relevant SSI scenarios and the appropriate use of questions and assessment to support the pursued learning outcomes (Ariza et al., 2016).

Phase 6: Design of SSIBL classroom activities
This phase is intended at rooting teacher professional development into daily practice at school. For this purpose teachers are encouraged to have a look at the media and select a recent new dealing with a topic of interest to their students. The topic has to be related to current scientific advances and its implications, be controversial and provide opportunities to get a better understanding, as well as the development of informed

opinions in students. Additionally, they are asked to identify connections with the existing curriculum, define learning outcomes and reflect on how to assess the process.

Phase 7: Reflecting back on how to improve the process
The final phase has a two-fold purpose: to promote students' communication and mutual learning and to provide opportunities for reflection and improvement. In this phase teachers presents their SSIBL activities to the rest of the group, discuss challenges and reflects on how to improve them.

METHODOLOGY

The purpose of this study is to demonstrate that our course based on SSBIL increases pre-service teacher's beliefs and knowledge related to that methodology. We have used a quasi-experimental pre-test post-test research design with pre-service teachers of primary education participating in general Science Education subject where our SSIBL course was embedded. In this study, the measurements have been done using some instrument developed as a part of the research process.

INSTRUMENTS: DEVELOPMENT, REFINEMENT AND VALIDATION

This section describes the process of refinement of an instrument originally developed to measure pre-service teachers' attitudes, beliefs and knowledge towards SSIBL approaches. Some of the items of the questionnaire express traditional visions of science education in which teachers use practical work to demonstrate scientific knowledge or provide correct and precise answers to problems. Other items reflect the main principles underlying the SSIBL model. In contrast with traditional visions, the SSIBL model recognises the importance of bringing authenticity into the classroom by connecting science education with current socio-scientific and intends to promote students' active engagement in inquiry and argumentation. Special emphasis is placed on the evaluation of different ideas and perspectives as an important requirement for educating critical and responsive citizens.

The refined instrument comprises 17-items that incorporate different constructs related with traditional and advanced pedagogies, as well as with the relevance and authenticity. The revised instrument was found to exhibit adequate ranges of internal consistency and reliability. As stated for some authors, labelling of constructs is a theoretical, subjective and inductive process (Pett, Lackey et al. 2003, p. 9) and respond to previous experience and needs regarding the underlying theory. Therefore "the meaningfulness of latent factors is ultimately dependent on researcher definition" (Henson & Roberts, 2006). We thought that chosen labels of constructs in this study reflect our theoretical and conceptual intent concerning SSIBL framework.

As stated for Romine et al. (2013), some of the challenges researchers faces in using instruments to measure attitudes and beliefs in science education is that they may be too closely tied to a particular project, length instrument format, limited reporting of psychometric, instrument that cover too many construct that are not sufficiently operationalized and last but not least some concerns related to validity (Romine et al., 2013, p. 264). Although these words are associated within the STEM education, measurement of students´ attitudes it could be extended to researcher concerns along the development or application of a new instrument.

Thus, sharing these concerns, to measure pre-service teacher beliefs regarding main dimension of our SSIBL framework, we decide to face the development of a validated instrument. Once this instrument was reliable and validated we could, not just identify pre-service teacher's beliefs, but also to measure what has been the effect of a SSIBL instruction in term of positive evolution of the pre-service beliefs and gains.

In this section we will present two instruments as a part of our main research exploring pre-service teachers SSIBL beliefs. The second instrument (questionnaire B) is a shorter and improved version of the first one (questionnaire A).

Based on some main dimensions emerged form SSIBL framework (Levinson, 2017) and specialized literature on SSI and IBL we developed a series of Likert-scale statements that conformed our first version of the questionnaire (Quesada, Ariza & Abril, 2017a).

The preliminary version consisted of a total number of 60 items organized in three main sections related to Inquiry-Based Learning Socio-Scientific Issues and Evaluation. For the survey, different sections were headed as "*In an inquiry-based learning setting …*", "*When using IBL…*"; "*To use SSIBL…*", "*When using SSI…*" and "*About evaluation…*". Based on our content research criteria, we mainly articulated those statement in 5 dimensions (Quesada, Ariza & Abril, 2017b) designated as **[GI-IBL]** (general issues regarding Inquiry Based Learning), **[G-IBL-D]** (guiding inquiry-based learning and deliberation), **[MPC]** (mapping controversy), **[AUT]** (Authenticity) and **[EVA]** (evaluation). We designated them regarding some teachers´ competencies defined at SSIBL framework. After we made that set of 60 statements, we submitted the questionnaire to 2 experienced science educators and we collected their feedback. We relied on these researchers to provide feedback regarding to what extend each statement were appropriately allocated within each dimension and to what extend the items could be refined to a better understanding of the meaning and within our research context. After experts' feedback, we made some minor changes in terms of rewritten some items and/or delete others. A final revisited version included a total number of 54 items. For each statement, pre-service teachers had to indicate to what extend they agree on a four-type Likert scale ranging from score 1 as "completely disagree" to score 4 as "completely agree".

Correlation between variables suggested to perform a factorial analysis. The KMO (Kaiser-Meyer-Olkin) sampling adequacy ratio reached the value of 0.776 and Bartlett's test of sphericity χ^2 (378) was 1590.40 ($p < .001$). Through these indicators a deep analysis of anti-image matrix, deemed that the answers were related, justifying the fulfillment of this analysis (Field, 2009). We carried out a previous exploratory factor analysis which seemed to show a structure of ten factors using the *eigen value* as cut-off, and eight component using the criteria of scatterplot (extraction method and rotation: principal component analysis with Varimax). The previous Exploratory Factor Analysis (EFA) on a reduced number of X statements showed a covariance value explained of 57 % for a total number of 8 components. Loading factors of the rotated components oscillated between 0.4 and 0.7 (for our sample size these should be approximately 0.420) (Quesada et al., 2017b).

These EFA results in terms of grouping variables and factor content through strictly statistical validation analysis, made difficult to interpret and classify the items according to the original content criteria that researcher proposed. Thus, we thought that this complex correlation among variables and dimensions revealed a high intricacy to have a composite validated instrument which gathered almost all main features for SSIBL teacher's competencies, as we originally pretended. This is understandable and reasonable in view of the strong interconnections between different SSIBL pre-service teacher competencies defined. For example, "asking questions that promote research" can be related to the ability to "map the controversy" and also with the perception of "authenticity". Thus, our content analysis revealed the limitations of grouping items into component and treating items solely on statistical outcomes.

Consequently, we decided to submit the questionnaire to a deep review. We examined the component structure, loadings outcomes and Cronbach's alpha from our initial EFA on questionnaire A. Then, we took some decision to eliminate items and just select those statements that fitted some of the original scales defined by researcher and with acceptable values of reliability for a composite construct and also for subscales suggesting some component structure. Considering some literature recommendations for the minimum statements for subscales, we added some new items (Table 1). Therefore, we decide to propose a new range of the Likert scale from 1 to 7. Table 1 shows some interconnections and redefinition of scales and components comparing questionnaire A and B.

Table 1

Instrument A and Instrument B subscales comparison

Instrument A		**Instrument B**	
(GI-IBL)		Q1 (2*), Q2 (3*), Q3 (11*), Q4 (**16***)	**(TRP)**
	4,6,7,9	Q5(6), Q6(9)	
(G-IBL-D)	12,**16***,17*, 21,27	Q7(19), Q8 (21), Q9 (23), Q10 (26), Q11 (N1),Q12 (N2)	**(ADP)**
(MC)	34,35,36,39*	Q13 (35), Q14 (N3)	
(AUT)	41,42,43,44	Q15(42), Q16 (43),N4 (Q17)	**(REL)**

N_x: New items

* Inverted statements

Qx: Renumbering and rewording items for instrument B. In brackets, original numbering in Instrument A

A final version for instrument B (annex I) consisted of 13 statements retained from questionnaire A. New 4 items (Q11, Q12, Q14, Q17) were redefined and incorporated in their corresponding section (N1-N4). Statements were grouped within 3 components which were named as "Traditional Pedagogy" **[TRP],** "Advanced Pedagogy" **[ADP],** and "Relevance & Authenticity" **[REL].**

After that, we piloted the questionnaire with a sample of 318 pre-service teachers enrolled at different compulsory subjects related to Science Education. For instrument B, the KMO sampling adequacy ratio reached the value of 0.887 and Barlett´s sphericity revealed a $\chi 2$ (136)=2043, $p<0.001$. These data estimated that the answers were substantially related, justifying the realization of an exploratory factor analysis (Table 2).

This EFA suggested that **[ADP]** could be explained through two components. Thus we have defined them as "Student Autonomy" **[STA]** and "Quality criteria for mapping controversy and deliberation" **[QMD].** We should report that some items showed cross-loading factors but with values behind 0.5. We calculated the composite and subscale reliability. Reliability for the whole instrument (all items included in the analysis, 17) revealed a Cronbach's alpha of 0.870. For the **[TRP]** was 0.721, for **[ADP]** was 0.875, presented as **[STA]** was 0.844 and **[QMC]** was 0.828; **[REL]** presented a value of 0.601. For this last component, as Cronbach's alpha in sensible to number of statements, this values could be acceptable because we only have 3 statements within it. All these Cronbach´s alpha values pointed out to a good level of reliability and item stability of the instrument.

Table 2

The rotated component matrix factor loadings for the 17-items Questionnaire B

	Component			
	1	2	3	4
Q1 (TRP)			.700	
Q2 (TRP)			.792	
Q3 (TRP)			.769	
Q4 (TRP)			.511	
Q5 (ADP)(STA)		.817		
Q6 (ADP) (STA)		.820		
Q7 (ADP) (STA)		.698		
Q8 (ADP) (QMD)	.534			
Q9 (ADP) (QMD)	.700			
Q10 (ADP) (QMD)	.598			
Q11 (ADP) (QMD)	.672			
Q12 (ADP) (QMD)	.563			
Q13 (ADP) (QMD)	.623			
Q14 (ADP) (QMD)	.543			
Q15 (REL)				.565
Q16 (REL)				.766
Q17 (REL)				.712

Extraction method: Principal component analysis:
Rotation Method: Varimax with Kaiser normalization
Rotation converged in 7 iterations. Variance explained: 59%

ANALYSIS, SAMPLE AND RESULTS

Analysis and sample

Data processing and analysis from this study were done using the SPSS statistical program for MAC V.22.0.

SSIBL modules were part of compulsory subjects related to Science Education for pre-service teachers. These subjects are part of the degree of primary education at University of Jaén. Participants were pre-service teachers (generalists) with different levels of training and multi-disciplinary backgrounds. This course was implemented along different academic years: i) 2015-2016, Cohort 1 ($N_{pre\text{-}test}$= 141 $N_{post\text{-}test}$=117, $N_{fit\ pre\text{-}post}$= 95), and Cohort 2, ($N_{pre\text{-}test}$= 107, $N_{post\text{-}test}$= 75, $N_{fitpre\text{-}post}$= 57); ii) 2016-2017, Cohort 3 ($N_{pre\text{-}test}$= 113 $N_{post\text{-}test}$= 109, $N_{fit\ pre\text{-}post}$= 98). Surveys were administrated using the google-formularies tool before and after the SSIBL course to that different cohorts of pre-service teachers. To fill questionnaires was not compulsory for pre-service teachers enrolled in the SSIBL course.

Results

Definition of subscales (using the researchers content approach) for instrument A has been quite valuable in terms of findings and results. This decision was supported for moderate Cronbach´s alfa for that subscales (0.530-0.856) (tables 3-4).

A deep analysis using those subscales an item-by-item approach for instrument A, showed that those gains and improvements had not equally been grasped within all pre-service facets regarding SSIBL.

Using this approach, main findings regarding some gains for SSIBL competences were related with different dimensions within that questionnaire such as: General Issues Regarding IBL (GI-IBL), Guiding IBL and Deliberation (G-IBL-D), Mapping Controversy (MPC) and Authenticity (AUT). As composite scale, pre-test result showed a value of 52.77 and post-test showed a value of 56.97 for cohort 1. This value meant a difference of total gain of 4.20 (this represent a gain of 6 % on the composite scale, Table 3). For cohort 2 this gain represented a 7%. Non-parametric tests revealed some significance differences ($p<0.05$) for pre and post results. In terms of size effect, we can describe it as small effect but close to medium (d: -0,99 r=-0,44; small effect $0.5<d>0.2$, medium effect $0.8<d>0.5$). What we really want to highlight is that in almost all statements, and instead, subscales and SSIBL facets, there were some pre-service teacher's gains regarding beliefs and knowledge related to SSIBL competencies.

Table 3

SSIBL pre-service teachers beliefs for pre-test and post-test Cohort 1 (instrument A)

	Pre-test Mean (SD)	**Post-test** Mean (SD)	**Cronbach´s alfa (post)**
(GI-IBL)	13,04 (1.42)	13,81 (1,73)	0.690
(G-IBL-D)	15,14 (1.74)	16,43 (1,80)	0.590
(MPC)	11,77 (1,46)	13,07 (1,44)	0.578
(AUT)	12,86 (1.46)	13,66 (1,58)	0.628
Composite Scale (GI-IBL)+(G-IBL-D)+ (MC)+(AUT)	52.77 (4.12)	56.97 (5.18)	0.851

Table 4

SSIBL pre-service teachers beliefs for pre-test and post-test Cohort 2 (instrument A)

	Pre-test Mean (SD)	**Post-test** Mean (SD)	**Cronbach´s alfa (post)**
(GI-IBL)	12.42 (1.71)	13.50 (1.68)	0.723
(G-IBL-D)	14.98 (1.91)	16.33 (1,89)	0.532
(MPC)	11.89 (1.83)	13.08 (1.77)	0.659
(AUT)	13.14 (1.84)	14.13 (1.78)	0.820
Composite Scale (GI-IBL)+(G-IBL-D)+ (MC)+(AUT)	52.43 (5.23)	57.05 (5.46)	0.856

Following a similar analysis done for cohort 1 and 2 but now using questionnaire B for cohort 3 we found that main gains took place in those statements related to an informed vision of teaching Science within our SSIBL framework, **[ADP]**. Post-test results showed gains in almost all different statements within all scales defined (Table 5). Nevertheless, gains in **[TRP]** and **[REL]** have shown that pre-service teachers did not acquire significant evolution in those dimensions. We can say that they kept their beliefs regarding some facets within this dimension. This results are aligned with research literature which reported that some teacher's beliefs are resistant to be changed**.** Regarding **[REL]** factor, pre-service teachers´ scores showed a very positive values before the SSIBL course started, which indicated a well-informed pre-service perception about of the authenticity in a Science Educational setting (mean score: 19.23 over 21 in pre-test and 19.45 over 21 in post-test, size effect 0.06 "irrelevant"). A possible explanation is that our sample is biased regarding their previous background and specific educational subjects which emphasized the pedagogical potential of authentic context. On the other hand, a result to be highlighted is the improvement of participants' beliefs and knowledge related to the **[ADP]** dimension. This dimension integrates the key features of the science education model being promoted and offers a promising result in the attempt to empower teachers as key players in the education of a society ready for RRI.

Table 5

Pre-test post-test results for Cohort 3 (instrument B used)

	Pre-test	**Post-test**	**Cronbach´s alpha pre-post**
	Mean (SD)	Mean (SD)	
(TRP) INV	8.75 (3.12)	8.37 (4.41)	0.610- 0.757
(ADP)*	56.93 (7.28)	60.98 (6.68)	0.847-0.890
(ADP)(STA)	17.37 (2.93)	18.90 (2.16)	0.804-0.779
(ADP)(QMD)	39.45 (5.07)	42.08 (4.94)	0,776-0.845
(REL)	19.23 (1.56)	19.45 (1.77)	0.423-0.689
ALL*	84.90 (7.20)	88.80 (6.27)	0.645-0.712

INV: inverted

*p<0.05

CONCLUSIONS

This work presents the research foundation of a teacher professional development program to equip teachers with the knowledge, skills, values and dispositions necessary to become key promoters of RRI through science education. Additionally, the work focussed on describing the process to design and validate some research instruments to measure teachers' beliefs related to science teaching in general and the science education, model for RRI in particular.

The process of development and validation of instruments has yielded two questionnaires. Statistics methods confirm the internal consistency of both instruments and a structure of components in line with the underpinning theoretical model. The second instruments resulted from a simplification of items and factors taking into account how the key dimensions of the model were interrelated.

The application of both instruments to different cohorts of teachers reveal a positive impact of the teacher professional development program on participant's beliefs and an evolution in line with a science education model for RRI.

This work is part of a broader one intended at getting a better understanding of how to best support teachers to promote RRI through science education. Data from the pre-post study of teachers' beliefs have been complemented with a qualitative approach including case studies and the analysis of the RRI-oriented classroom activities designed by teachers (Romero-Ariza et al., 2017).

ACKNOWLEDGEMENT

This work has been conducted within the PARRISE project and received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 612438. www.parrise.eu

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Received: July 7, 2017

Final version received: October 26, 2017

Published online: October 31, 2017

ANNEX I. QUESTIONNAIRE B

Instructions: *Please select to what extend do you agree with the following statements (1 completely disagree to 7 completely agree) (*)*

When using a SSIBL approach for science education**…**

Q1 …practical tasks have to be designed to demonstrate what teachers have explained before.

Q2 …tasks have to be solved by giving a precise and clear answer.

Q3 ... the teacher should finally show the correct answer.

Q4 ...the teacher has to make sure that students follow his/her explanations

Q5 ...students should be given opportunities to express and explain their own ideas.

Q6 … students should discuss and evaluate different ideas and strategies.

Q7 … after making a question, teachers have to give enough time to student for thinking and responding.

Q8 … students have to listen to, respect and evaluate different ideas.

Q9 …teachers can build on their students' explanations to respond to other students who are their schoolmates.

Q10 …students think about their own wrong ideas.

Q11…teachers support students in the development of evidence-based arguments.

Q12… different ideas are evaluated according to their potential to explain evidence.

Q13 … students are given opportunities to evaluate both scientific and moral/ethical arguments.

Q14 … teachers support students to reflect about the social, economical and ethical consequences of scientific advances.

Q15 …it is important that students choose their own topics for inquiry.

Q16 … it is important make connections with students´ daily experiences.

Q17… students get deeply engaged in science learning when they can see the utility to what they are doing.

*Authors' notes: the questionnaire was originally developed and validated in Spanish. For the purpose of this article the statements have been translated into English, thus meanings might varied slightly. Likert *Scale numbers were explicit shown.*

Statements are distributed into three main components identified as:

- Traditional Pedagogies [TRP]: Q1-Q4
- Advanced Pedagogies [ADP]: Q5-Q14
- Relevance and Authenticity [REL]: Q15-Q17