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Title

Innovative Teaching of Responsible Research and Innovation in Science Education

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Abstract / Summary

This study investigates how the ENGAGE HUB can support teachers' to develop new strategies to equip students with knowledge and skills. The European project ENGAGE (engagingscience.eu) aims is to increase awareness of Responsible Research and Innovation (RRI) through Inquiry Based Learning (IBL) by reaching 12.000 teachers and 360.000 students in 14 countries. It combines OER, MOOC and CoP (Community of Practice) and targets three components: students' interest, science knowledge and inquiry skills. This qualitative analysis focuses on the first year of ENGAGE HUB in the UK with 3,500 teachers and 18,000 materials downloaded. Findings indicate more than seventy strategies shared by teachers on how students are engaged through dilemma materials. Teachers' examples present evidence that learning science concepts can be set within the context of its implications to society. Their innovative practices suggest ENGAGE lessons help students think, discuss and extend their knowledge through possible future scenarios that make the pros and cons of technology more concrete. In this context teachers play an important role for making science more relevant to students' concerns, which are known to be future orientated. This might increase the likelihood that students can apply what they have learned outside school and respond to societal challenges.

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Body

1. Introduction

The 21st century is marked by the fast advancement in Science and Technologies. Latest discoveries related to various emergent fields such as nanotechnology, artificial intelligence, biotechnology are frequently announced to citizens through science-in–the-news. These daily innovations indicate various issues closely connected to citizens' lives, for instance, food security, enhanced health, energy and environment. On the other hand, the impact of scientific innovations is unpredictable and implies scientific knowledge and skills for reflecting on social and ethical implications. This requires societies being able to deal with promises and uncertainties, particularly to develop better understanding of its potential benefits and risks (Sutcliffe, 2011; Von Schomberg 2013).

Education plays an important role in this contemporary scenario (Ratcliffe & Grace, 2003). The European Commission has highlighted the importance of Responsible Research and Innovation (RRI) in Science Education through its Science in Society programmes (FP7 and Horizon 2020) (Sutcliffe, 2011). Various European projects have been helping teachers foster students' inquiry based learning (IBL) skills for them being able to discuss socio-scientific issues (Okada et al, 2015). Some of recent initiatives have been also highlighting the importance of students developing evidence-based opinion related to science in their lives, such as the ENGAGE project (Sherborne et al., 2014).

The ENGAGE project aims at spreading the teaching and learning of RRI at scale, by connecting cutting-edge Science and Technology with inquiry based learning. This study describes the ENGAGE HUB framework, which integrates "educative materials (OER) for students, communities of practice (CoP) and Open Online Courses (MOOC) for teachers. This qualitative investigation focuses on how the ENGAGE HUB can support teachers' to develop new strategies to equip students to apply science knowledge and develop RRI inquiry skills (Fig. 1). A big challenge for teachers is to change how science is taught (Hoban, 2002, Dwyer et al., 1991). This requires innovating teaching's practice. That means moving from teaching focused only on science as a body of content to equipping students with knowledge, skills and values to use science in society. In order to tackle this issue, our research questions focus on what the challenges and opportunities are for teachers to innovate their practices through the ENGAGE HUB.

2. Integrating Responsible Research and Innovation and Inquiry Based Learning

The RRI curriculum developed by ENGAGE (Fig. 1) presents a framework which integrates science-in-society knowledge and inquiry skills. It is based on European curricula and the US Next Generation Curriculum Science Standards (NGSS). Science-in-society knowledge refers to four key areas: Technology impact, Big Science, Values thinking and Science-Media.

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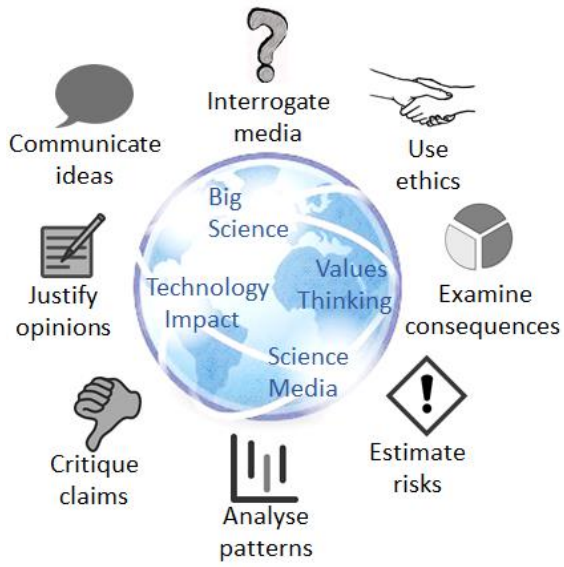
- **Technology Impact:** Technological and Scientific developments are the basis for a better future but must be planned carefully in order to maximise the benefits and reduce risks, particularly any harmful impact.
- **Big Science:** Science is no longer an individual search for knowledge, but a collaborative and complex enterprise, done in teams. Funded largely by corporations and governments and politically determined, it favors practical applications and key areas in society. This means responsible innovations must address societal needs in accordance with societal values such as people, environment and economy.
- **Values thinking**: In emerging science and technology, there are often uncertain issues with unclear implications that require socio-ethical thinking. Decisions should be made by taking into account the views and concerns of various perspectives and actors in societies.
- **Science-Media:** Much of our scientific information is interpreted by the media, who may give an unbalanced, biased, black and white or sensationalised account. The source of information needs to be assessed in terms of its purpose, scientific credentials and recency. Critically read media reports about science, identify the data, evidence and values thinking used to back up the claims, as well as evaluate its strength in terms of repeatability and reproducibility.

Fig. 1. RRI curriculum: Science knowledge and Inquiry skills (Okada et al, 2015)



RRI consider that technology and science progress are the basis for a better future. However innovations must be planned carefully to address societal needs in accordance with societal values in order to maximize the benefits and reduce any harmful impact. Therefore, citizens should be involved in understanding these four areas and develop inquiry skills to form evidence-based opinions on societal needs and social values. With this purpose, scientific inquiry skills integrated to RRI focus on eight abilities listed below:

1. **Interrogate Sources**: questioning different sources and assess their validity and trustworthiness by judging the reliability of the source, check for bias and evaluate evidence for claim.
2. **Use ethics:** understanding that scientific reasoning can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.

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3. **Examine consequences:** evaluating the merit of a solution or competing solutions to a real-world problem, based on scientific ideas and principles, empirical evidence, weighing up benefits and risks and/or logical arguments regarding relevant economic, societal, environmental and ethical considerations.
4. **Estimate risks**: measuring risks and benefits by assessing its probability. To weigh up a risk means combining its probability and the scale of the consequences, and balancing against the benefits to the individuals or groups affected.
5. **Analyse patterns:** interpreting observations and data in a variety of forms to identify patterns and trends, making inferences and drawing conclusions.
6. **Critique claims:** check strength (quality accuracy and sufficiency) of evidence provided and identify lack of clarity of justification Comment on whether the reasoning follows logically from the evidence, and provides strong support to the claim.
7. **Justify opinions:** synthesising scientific knowledge, implications, and value perspectives into an informed opinion describing key arguments supported by empirical evidence and scientific reasoning, and identifying values based thinking, to support or refute a viewpoint on an issue or a solution to a problema.
8. **Communicate ideas:** Being able to effectively describe opinions and accomplishments with text and illustrations, both orally and in writing, in a range of formats, using the major features of scientific writing and speaking.

The ENGAGE project offers three kinds of OER for teachers to support students to develop the RRI inquiry skills described above:

I) Dilemma lessons: refers to a short lesson based on a set of activities to engage students with productive socio-scientific issues and support them to extend and evaluate their learning with group discussion. Various online multimedia resources are included in the ENGAGE materials, for instance, slide presentation with activities for students, guidelines for teachers with pedagogical suggestions, and web links with science-in-the-news or video clips with scientists. These OER refer to controversial socio-scientific issues related to applications and implications of science introduced to students at the beginning of a lesson.

A scientific dilemma must be engaging, authentic, controversial, covered by the curriculum, social and related to RRI. Its aim is to provide a productive learning context to capture students' interests to discuss and extend their understanding for developing evidence based opinion.

Group Discussion refers to a small team with 3 to 4 student whose aim is to share understanding about a scientific dilemma and practicing arguing and reasoning together. For that, students will need prior knowledge to extend their learning and articulate their own ideas with their peers. They can check evidence, evaluate arguments and compare solutions together using online templates

For instance, in the following example (Fig. 2), students are presented with PowerPoint slides presenting GM technology in a negative light to add controversy and provoke discussion. They are then given the dilemma 'will you buy GM cereal?' Then, students work in groups looking at statements about GM food. After reading each one, they discuss the question "does the statement support the claim that eating GM free cereal is a risk to your health?" The group needs to reach a consensus before moving onto the next statement.

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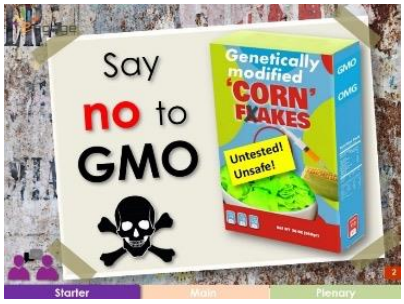
Figure 2 - ENGAGE dilemma material: GM decison (EngagingScience.eu)



II) P**roblem-solution lessons:** refer to a series of two or more lessons with more advanced activities also presented with PowerPoint slides to teach inquiry processes, help students explore ways to solve problems and explain solutions through argumentative conversations. It refers to provocative problem emerging from a real life issue. The requirements for the problem are similar to the six criteria for a 'scientific dilemma', but it includes also "Need to know". It covers the whole inquiry process and science concepts for students to solve the problem. Students will gain insight into not only the skills, but also the science concepts and principle involved in carrying out the processes (e.g. data analysis).

Conversation refers to whole class debate based on four steps sequences of questions for argumentative thinking with the aim to support students develop evidence based solution. First, teachers select questions designed to activate or provide students with the essential background knowledge. Second, they organise concepts and facts into evidence. Third, they elaborate opinion and justification using argumentation (claim, evidence and reasoning) Fourth, the teacher organises a whole class debate through some suggested or adapted methods. The aim of the conversation is to support high quality argumentation and final outcomes, which explain problems-based solutions.

For instance, in the following example (Fig.3), students are set the problem of deciding whether they would sign a petition in support of a ban on animal testing. In the first lesson, students apply their knowledge of the gas exchange system to explain what causes asthma and why new drugs are needed to treat it. They look at scientific evidence to decide how essential animal testing is in the development of new asthma drugs. This is designed to put the problem into a scientific context relevant to the curriculum. In the second lesson they are introduced to three types of ethical thinking through a game based on a reality television show. The aim of this is to introduce a new skill through a familiar and engaging setting. They then apply these principles and practice the skill of ethical thinking by looking at ethical arguments for and against a ban on animal testing, which they use in a class debate (conversation). By the end of these two cycles, the students are equipped with both the scientific concepts and principles which they need to respond to the original problem.

Figure 3 - ENGAGE problem-solution material: Animal Testing (EngagingScience.eu)

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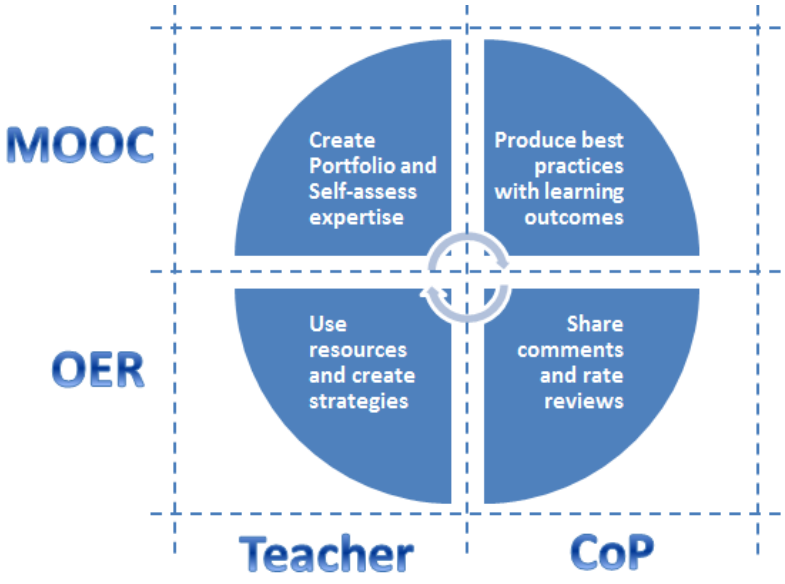
III) Scenario-based topic: refers to a group of lessons to teach science content and inquiry skills ending in a performance assessment. Students will investigate more independently by practicing inquiry skills, applying science concepts and developing awareness of responsible actions. Scenario-based learning helps teachers to create inquiries which blend content and process teaching into a compelling scenario about contemporary science. Instead of having purely academic goals and largely disconnected lessons, a Scenario-based topic weaves the content and process teaching into the scenario, as waypoints towards achieving the goal. The scenario is structured into stages, where a question or need for information launches a teaching episode, or student inquiry.

Performance assessment helps teachers and students use ENGAGE tasks to assess students' learning of RRI/inquiry processes and content. It aligns curriculum and assessment, taxonomy of learning objectives and uses rubrics to assess student work.

3. The ENGAGE HUB for Teacher's professional development

The ENGAGE HUB (EngagingScience.eu) provides IBL focused OER for developing pupils RRI skills and MOOC for teacher's professional development. This online environment was developed using WordPress for just-in-time OER production based on Science-in-the-news. It was configured as a network of sites (WPMU) in order to have a site for each language and linked to social media platforms, e.g. SlideShare, YouTube, Pinterest, Facebook and Twitter. The EdX MOOC login system was integrated to the WordPress with automatic authentication to facilitate user access to online courses. Its video library was setup on YouTube and is focused on teachers' interests, needs and productions. MOOC was designed to support teachers' best practices and promote knowledge exchange to foster their CoP. A set of widgets was embedded around content for teachers to share preferences, opinions and reviews. Their user profile was extended to include their professional development pathway based on their interactions on both the OER and MOOC environments (Okada et al., 2015).

Figure 4: ENGAGE HUB (Okada et al, 2015)



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The Knowledge Hub (Fig. 4) is open to any visitors to access OER and its reviews by the community. After signing up, participants as members can use, adapt, rate and comment on three types of OER and apply its respective RRI tools. Open online courses provide teachers with opportunities to understand the principles related to each RRI tool and develop teaching skills efficiently. These mini open online courses were designed to be short and address teacher's needs to embed OER successfully in their lessons particularly using toolkit to innovate their practice as reflective practitioners.

Teachers can act as reflective practitioners (Shulman, 1986), by keeping their professional development pathway updated in the CoP through self-assessment and own online portfolio of OER that they have adapted. These features aim to build a sense of community by facilitating interaction between members and rewarding committed practitioners. The platform gathers evidence on OER usage and comments or reviews posted about achievements with OER or in the MOOC environment. Through accumulated interaction with the ENGAGE Hub they can also be recognised as experts within the CoP.

Teaching in a RRI context requires teachers to learn new skills and a significant teaching change. There are various barriers pointed out by previous ENGAGE research in eleven European countries related to embedding RRI in science curriculum (Kikis-Papadiskis & Chaimala, 2015). For instance, schools must follow a predefined curriculum, teachers do not have much flexibility to implement new lessons, national curriculum exams focus on science content and in general educators are not prepared nor do not feel confident to change their practice.

In order to face all these challenges, the ENGAGE RRI HUB was designed, to support the teachers' CoP to facilitate the growth of teachers' conceptual and practical knowledge through OER and MOOC gradually by the following three stages: adopt, adapt and transform (Aikenhead, 1994). These three stages indicate the degree to which science and society content is integrated with traditional science content for learning:

- **Stage 1 Adopt:** minor change – extending topics already taught with dilemma lessons. It presents little RRI content for motivational purposes to be applied in short lessons.
- **Stage 2 Adapt:** significant changes – teaching inquiry processes with problem-solving lessons. There is a casual infusion of more RRI content but with no explicit purpose.
- **Stage 3 Transform:** major changes – teaching science content with a Scenario-based topic. There is a purposeful infusion giving even more time to RRI.

The ENGAGE RRI HUB considers, firstly, teachers might adopt new teaching strategies to their repertoire by using an easy-to-use material for one short lesson. This might add extra benefits, such as "topical dilemma materials" for attracting students to extend their learning through group discussion. Secondly, teachers might feel more motivated to adapt their existing practice to fit more exciting "problem solving materials" including argumentative conversations into their curriculum. Once teachers are aware that they can integrate RRI and IBL in their lessons as well as address the national curriculum needs; they might be able to complete the transform stage. This means to equip students for integrating conceptual knowledge, inquiry skills and societal values in order to solve "controversial scenarios related to socio-scientific issues". Additionally, through assessment performance, they might also be able to assess students' innovative learning and provide evidence of innovative teaching.

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4. Methodology

The qualitative approach based on virtual ethnography comprises of four steps. First, this study investigated online comments, discussions and suggestion shared by teachers in the OER and MOOC. Second, data from surveys available in both environments, WordPress and EdX, was analysed. Third, quantitative data from its users' analytics was also considered to identify most popular and commented OER (materials and tools), including teacher's strategies. Fourth, the application tool LiteMap was used to categorise data, visualise patterns and support qualitative analysis. This tool provides a dashboard with various visualisation which was used to analyse the ENGAGE CoP collaboration.

Qualitative data comprise comments and reviews about OER by teachers in the CoP (June 2014 to June 2016) and MOOC (July 2015). Teachers' suggestions and strategies were categorised and grouped in categories based on the "short" inquiry cycle: ENGAGEMENT <=> EXTEND <=>EVALUATION (Bybee, 2006) for 1 lesson:

- **Engagement:** activities are designed to help teachers promote curiosity and elicit students' prior knowledge. Students are encouraged to make connections between past and present learning experiences, expose prior conceptions, and organize their thinking toward the learning outcomes.
- **Extend:** activities also support teachers to challenge and extend students' conceptual understanding and skills. The students are asked to apply their knowledge and skills for elaborating questions, comparing facts and opinions, and develop their evidence-based conclusion.
- **Evaluation:** activities also encourage students to assess their understanding and skills. It also provides opportunities for teachers to evaluate students' progress toward achieving the learning outcomes.

Teachers' comments in the OER Hub and MOOC environment were also analysed through LiteMap (http://litemap.net) a mapping application for mapping collective knowledge of online communities. These comments were classified in 6 categories (see Fig.5): (pink) materials, (purple) year group, (brown) strategies, (green) benefits, (red) challenges and (grey) learning outcomes. LiteMap provided useful visualisation about these categories emphasising nine materials.

5. Findings

During the first year after the launch of the OER platform shows that ENGAGE UK reached beyond its target with 3,125 teachers registered and 18,368 materials downloaded. The three most accessed materials had more than 1600 visits and the four most popular materials shows more than 250 files downloaded. Approximately 60% of users access various resources and 75% return to the website. The average time of users on the website is 5 minutes.

Qualitative data from comments and reviews about OER by teachers in the CoP (June 2014 to June 2015) and MOOC (July 2015) showed evidence on how they have been using dilemma material and group discussion to innovate their practice. It was possible to map strategies, challenges and benefits. The majority of teachers who used ENGAGE declared that OER were effective for engaging students with the activities, including videos and resources on both OER portal and MOOC environment. There were three key categories that emerged from data analysis used to highlight evidence about how teachers are using ENGAGE HUB to innovate their practices. To illustrate those categories a few examples were extracted from a list of more than 70 strategies (Okada et al, 2015) as evidence on how teachers are moving from instructional lessons based on delivering science concepts to promote engagement with dilemma discussion for student applying knowledge and skills.

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5.1 ENGAGEMENT

a. Use scientific dilemma for activating students' curiosity and interest:

- *Make the context more fun with real demonstrations OER (Eat Insects) 03/07/2015* AL
- *Create opportunity for students to ask more questions than look for answers MOOC(UK01) 10/07/2015* JW

b. Set science-in-context to capture student's attention with Science:

- *Making the newspaper articles 'consumable' for student annotation. OER (Giant Virus) 27/06/2014* PH.
- *Promote student's reflection on various perspectives of socio scientific issues presented by real people on resources (e.g. Youtube) talking about the real problem MOOC (UK01) 27/07/2015* JDI

c. **Recall student's previous knowledge to discuss the dilemma:**

- *Prompt students with concepts that they might know and ask them to make connections with the dilemma MOOC (UK01) 16/07/2015* JO
- *Ask students to bring questions about science concepts to share useful knowledge related to the dilemma OER (Car Wars) 19/07/2015* AE

5.2 EXTEND

a. Help students apply their knowledge to develop their own opinion:

- *Apply easy-to-use templates and worksheets suggested in the materials OER (**Take test**) 24/02/2015* HK
- *Be aware of ongoing research that can be useful to extend the topic OER(Grown your body) 15/05/2015* CB

b. Guide students to apply inquiry (RRI) skills to find best solution or evidence-based opinion

- *Ask students to choose favourite outcome: report, online news, presentation. OER (Ban-the-Beds) 14/09/2014* BE
- *Identify skills that students need or want to practice e.g. of interpretation, data analysis, discussion MOOC (UK01) 18 07 2015* JL

c. Support students to justify their overall decision making

- *Guide students to balance discussion and explain decisions or opinions with arguments and evidence (using knowledge and facts) MOOC (UK01) **20/07/2015*** JW BR
- *Use teacher's guidelines to help students develop persuasive argument. MOOC (UK01)16/07/2015* VC

5.3 EVALUATION

a. **Get feedback to improve performance:**

- *Discuss with students skills that they developed or need to improve: data analysis, arguments, conclusion MOOC (UK01) 20/07/2015* JU
- *Ask a department discuss how the lesson could be expanded to include fieldwork, numeracy, PSHCE etc. MOOC (UK01) 10/07/2014* Y78

b. Teachers will also need to reflect on what their students learned from the lesson and how:

- *Identify and discuss about misconceptions MOOC (UK01)* DE
- *Reflect with students: what different ways could they assess the outcome of their learning? MOOC (UK01) 18 07 2015* JW

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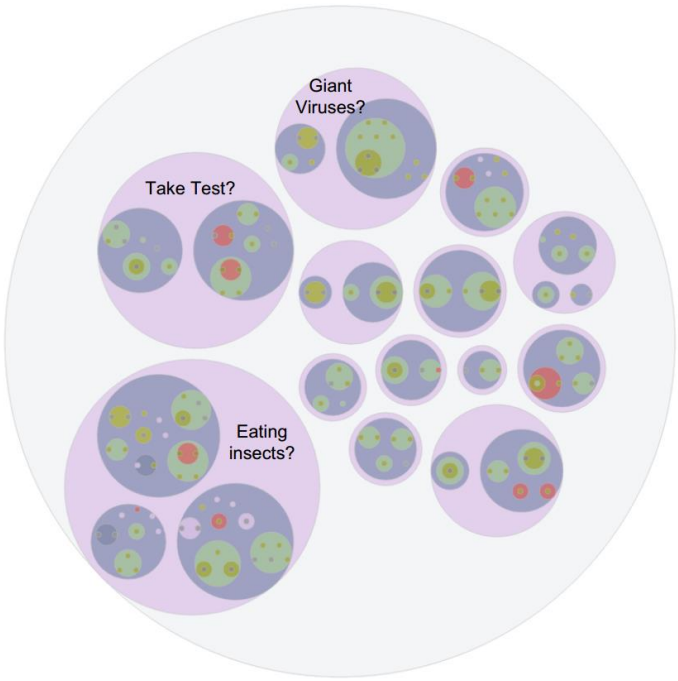
Figure 5 created through LiteMap tool shows teacher's comments on specific OER (pink circles). The most popular resource in the UK was "Eating insects" with more than sixty five comments. Teachers mentioned that they applied this lesson with three curriculum groups (purple circles): Year 7, Year 8 and Year 9. For each year group, they highlighted some benefits (green circles), such as "*useful science-in-the-news weblinks*" and challenges (red circles) such as "*I had to modify it to fit better to Y9*". Then, some strategies (brown) were mentioned related to each benefit or challenge,, for instance "*web links suggested in the resources help teachers to set up science in context*" some of them with learning outcomes (grey) such as "*Students were really engaged in discussion using persuasive language*".

In general, the majority of teachers highlighted diverse benefits (green circles) about materials related to students' engagement, useful resources, flexible materials, up-dated content, exciting multimedia, and meaningful activities. A few challenges were mentioned by teachers (red circles): some activities were short for the lesson; motivated students could work more, students that do not have enough knowledge on the topic find it difficult to participate in the dilemma lesson and group discussion, more guidance in assessing students' learning would be useful.

Figure 5 - Teachers' comments in the OER Hub and MOOC environment with LiteMap (Source: Okada et al., 2015)



In the ENGAGE CoP, teachers provided evidence about positive outcomes (grey circles) with clear examples, such as students developed various skills particularly debating, arguing, evaluating and writing. The comments below extracted from data analysis were selected to illustrate teachers' achievements related to the 8 RRI skills:

- **Interrogate Sources**: S*tudents commented that they could have been reading different stories! At this point I (teacher) explained that they were the same "issue" but in different papers. OER (Giant Virus) 27/06/2014* JT

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- **Use ethics:** *The series of lessons offered an extra dimension for the students to hook their knowledge and understanding scientific issues, for example: genetic inheritance onto, the dilemmas of taking a test, the ignorance of some and possible "prejudice" of others. OER (Take test) 21/04/2014* GZ
- **Examine consequences:** *Students were stimulated to look at all the issues surrounding the dangers of this virus and vaccination pros and cons. OER (Ebola) 31/10/2014* LE
- **Estimate risks**: *A lot of pupils knew benefits but not the risks of scientific issues, e.g. they were able to explain what a tanning bed is, but none the danger linked to it. OER (Ban-the-Beds) 14/09/2014* PC
- **Analyse patterns**: *Students used real data suggested in the materials to bring questions, analyse and interpret OER(Solar roadways) 17/12/2014* LE
- **Justify opinions:** *Students were able to integrate science knowledge and inquiry procedure, for instance, to elaborate the menu for the canteen by describing sourcing the insects with detailed information. OER (Eat Insects)* 17/07/2015 BE
- **Critique claims:** *Students questioned other groups' beliefs and the level of concerns OER(Giant Virus) 27/06/2014* JT1
- **Communicate ideas**: *Students practiced various inquiry skills: elaborating argument, arguing and communicating science MOOC (UK01)* X1

6. Discussion

This study focused on how the ENGAGE HUB can support teachers' to develop new strategies by using dilemma OER which integrates RRI integrated to IBL, supported by MOOC and CoP for professional development. Various investigations highlight the importance of CoP for continuing professional development (Buysse et al. 2003; Wenger, 1998) and supporting teaching-led innovation (Burden & Hunt, 2010; Toole & Louis, 2002; Little, 1982 and Rozenholtz, 1989). Some of these studies indicate that teaching is more effective in schools, which operate as professional learning communities, where all participants learn with each other (Little, 1982; Rozenholtz, 1989; Grossman et al., 2001) or innovation ecosystems - interconnected learning for improvement (Hannon et al., 2011).

The ENGAGE CoP is still in its initial stage of development between coalescing and maturing (Wenger, 1998) So, ENGAGE members are still building relationships mainly through MOOCS and workshops. Participants are still discovering what useful knowledge can be shared (Shulman, 1986) and their key drivers for innovation. Hargreaves (2004) highlights various drivers for teachers' innovation combined with network communities: teachers often adjust materials and share new strategies to help students learn. They also look for creative opportunities for improving professional skills especially to meet changing circumstances. Innovation can be considered a way of learning professionally, it empowers teachers to enrich their practices to improve students learning including their own innovations to succeed at their studies, work and life.

Innovative CoP takes time to consolidate, the ENGAGE facilitators and researchers will be investigating together how to build stronger bonds among the teacher community to create enough energy and momentum to sustain inter-action and identity during the next two years of the project. As Nuffield Review (2009) has pointed out, educators need the kind of professional development and resources that meet their teaching concerns and enrich their knowledge of addressing the learners' needs.

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During this investigation based on the first year of ENGAGE in the UK it was possible to identify that there is not enough research to know the effects of communities of innovative teachers on student's innovative learning (Muijs & Harris, 2003) and how to scale up innovative classroom practices.
In ENGAGE, evidence shows that teachers in the UK started to share not only benefits or challenges they faced to innovate their practices, but also examples on how materials, tools and their strategies can be used for their students' innovative learning. Excellence in education according to Hattie (2009) occurs through visible teaching for visible learning when teachers are able to see learning through the eyes of their students and prepare students to see themselves as their own teachers. Teacher's strategies and examples shared in the ENGAGE Hub indicate that dilemma lesson allow them to identify what students understood from science concepts when they applied knowledge and skills to discuss the dilemma. Teachers mentioned that they were also able to identify misconceptions and gaps. Their comments also suggested that efficient procedure for Inquiry Based Learning might help learners to understand how to learn and teach themselves. In addition strategies and outcomes of group discussion in dilemma lessons indicate that individuals and groups can learn from each other as well as from their own reflection particularly during evaluation activities.

However, the examples provided by teachers are not enough to assess the impact of RRI teaching on students' learning. Most of the teachers' comments generalise the outcomes for the whole class, and just a few of them were able to mention outcomes of specific students. The current challenge for teachers is to be aware of what each student, group or whole class is thinking and knowing (Hattie, 2009; OECD, 2014). So teachers must establish success criteria for their lessons, create opportunities for learners to construct and reconstruct knowledge and ideas, and provide meaningful feedback for each student progress on their learning goals. In ENGAGE, this will be expected during the transform phase with scenario-based topic and performance assessment, where teachers will prepare a set of lessons for students to develop knowledge and skills, interact with experts or scientist; and be aware about their learning achievements.

7. Conclusion

This research is timely since Responsible Research and Innovation (RRI) in Science Education is emerging and there is a lack of studies in this field. Although there are various RRI projects funded by European Commission such as ENGAGE (engagingscience.eu), most of these initiatives are recent. It is clear that there is a need for further research, particularly on the effect of teaching innovation of RRI and IBL for equipping responsible innovative learners at scale.

Previous research (Kikis-Papadaskis & Chaimala, 2015) shows various barriers and challenges for teachers to innovate RRI teaching in Europe. By discussing together both the ENGAGE framework for teachers' CPD, which consider those challenges, as well as, strategies suggested by the own teachers of ENGAGE CoP; we hope to find practical ways of approaching the initial key issues in this area: How could teachers start their teaching innovation with RRI and IBL? What might be the initial effect of teaching innovation through dilemma and group discussion on students' learning? What are the next challenges for ENGAGE CoP of innovative teachers?

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Our findings related to one year of the ENGAGE project are encouraging. Even though the teachers' CoP in the UK is on its initial stage of development, participants' comments show various strategies about how to innovate with dilemma and group discussion as well as a few challenges and positive outcomes on students' learning. The next stage of our work is to integrate the research outcomes of the ENGAGE consortium, which includes 14 countries. Our next investigation will also focus the uses of ENGAGE CoP during the Adapt phase with problem-based solution materials and the argumentative conversation tool. If ENGAGE CoP can be fostered successfully, this might help a higher number of teachers to reach the Transform phase. Therefore, it will be possible to find new ways to address the problem outlined at the beginning of this paper - how to equip the next generation for active engagement in Science.

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