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# Informal chemistry education: a missed opportunity?

## Educació informal en química: una oportunitat perduda?

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**abstract**

Science, technology, engineering, mathematics and medicine (STEMM) disciplines are increasingly shaping our lives and the world we live in. With this in mind, there is concern that skills shortages could impact on national and global economies. Addressing challenges across these areas requires engaged and informed citizens and also a pool of STEMM professions, for the present day and the future. This paper will focus on the bodies of research that shape this dialogue, specifically, attitudes towards science, public understanding of science, scientific literacy and work undertaken in the area of outreach and public engagement leading to informal and non-formal learning with a particular focus on chemistry related programmes.

**keywords**
Outreach, public engagement, informal education, non-formal education.

**resum**

Les disciplines de ciència, tecnologia, enginyeria, matemàtiques i medicina (STEMM) configuren cada vegada més les nostres vides i el món on vivim. Tenint en compte això, hi ha la preocupació que la manca d'habilitats en aquests àmbits pugui afectar les economies nacionals i mundials. Afrontar els reptes en aquestes àrees requereix ciutadans compromesos i informats i també un grup de professions STEMM, per al present i per al futur. Aquest article se centrarà en els organismes de recerca que configuren aquest diàleg, específicament, en les actituds cap a la ciència, la comprensió pública de la ciència, l'alfabetització científica i el treball realitzat en l'àmbit de la divulgació i el compromís públic que condueix a l'aprenentatge informal i no formal amb un enfocament particular sobre programes relacionats amb la química.

**paraules clau**
Divulgació, compromís públic, educació informal, educació no formal.

### The importance and value of science

There are many differing motives for how and why scientific pursuits, specifically science education, are deemed valuable. Osborne, Simon & Collins (2003, p. 1051) noted that «the nation's standards of achievement and competiveness are based on a highly educated, well trained and adaptable workforce». Osborne and his team also observed that «the low uptake of mathematics and science and the negative attitudes towards these subjects poses a serious threat to economic prosperity». This has long been on the agenda for the European Union (European Commission, 2004) and the United States of America (National Academies, 2005), with a perceived need for scientists to contribute to the achievement of economic growth, and research stressed as a key priority for tackling societal challenges (RRI, 2013) and delivering impact (fig. 1). More recently, investment into strategic applied research has been prioritised in Ireland as an aid towards economic recovery (Science Foundation Ireland, 2015; OECD, 2007). With public money being put towards applied research in difficult economic times, the agenda turns towards the level of responsibility scientific researchers have in communicating and engaging the public with their research. Science Foundation Ireland's strategic plan for 2020 stated that an engaged public is one that understands the role of science; can judge between competing priorities and arguments; encourages young people to take science, technology, engineering and maths (STEM) subjects, and feels that has the appropriate level of engagement with, and influence upon, the researchers (Science Foundation Ireland, 2015, p. 23).

We are in a landscape where this is a «widely entertained societal obligation» on the part of scientific institutions to offer «the public» social impact an engagement in research policy (Bauer, 2016; Ziman, 1984).

*Figure 1. Potential impact areas for research: culture & society, economic, capacity building, health & wellbeing, environmental, internationalisation, policy & professional services, and product development.*

In parallel to this effort, contemporary science education reforms (Duschl, Schweingruber & Shouse, 2007; National Research Council, 2000, 2012; Millar & Osborne, 1998) place a significant emphasis on developing scientifically literate citizens. The importance of this is founded upon the notion of a *socio-scientific citizen*, one who understands the nature of science, and how it can impact upon their life, and who can also actively participate in debates and decision-making regarding scientific issues (Dillon, 2009; Roth & Calabrese Barton, 2004). This thinking has been picked up by policy makers and is now firmly embedded in national and international policy documents. This has led to the importance of communicating the impact of scientific research becoming even more pronounced (fig. 2). Policy documents (European Commission, 2007; Department for Jobs, 2011; European Commission, 2011), research institutes and funding bodies require outreach and public engagement as a pathway to research with impact (*e.g. Research excellence framework*, 2014).

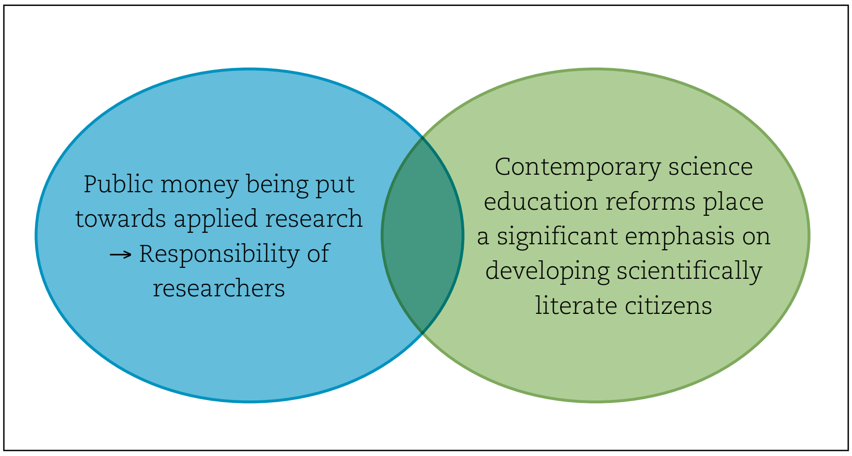


*Figure 2. Combination of parallel efforts.*

Both movements align in their drive towards a more informed and scientifically engaged and literate citizenship. However, many scientific researchers are not always equipped to actively participate in outreach and public engagement initiatives, and when they do so may frequently not embrace pedagogical or communication best practices. And the differing and sometimes competing goals of communication, for example, PAS (public awareness), PES (public engagement), PPS (public participation) and PUS (public understanding) (Sanden & Meijman, 2008), and justifications for communicating research can be confusing (Bray, France & Gilbert, 2012). Therefore we can understand that, science communication through public engagement is frequently aimed at educating the public about current scientific developments, and potentially their ethical and moral implications (Bauer & Jensen, 2011; Davies, 2008; Mathews, Kalfoglou & Hudson, 2005). These events may lead to the public learning more about the content of science, enhancing their views of science and scientists (Christidou, 2010; Christidou & Kouvatas, 2013), and, in the case of school students, also gain an insight into the broad range of career possibilities that science has to offer (Archer, 2013; Cleaves, 2005).

**Barriers to communication**

There are numerous barriers to the communication of science, which draw from key areas of a broad number of fields: science education, science communication, psychology, policy, philosophy, sociology, marketing and the traditional sciences (Mulder, Longnecker & Davis, 2008). Scientists more often than not do not have any training or experience in science communication, and Bray, France & Gilbert (2012) note that the public deficit model continues to «haunt» the science communication literature (Bauer, Allum & Miller, 2007). Furthermore, a number of studies have indicated that many scientists lack an appropriate skillset for successful communication and public engagement, or that the training opportunities to develop these skills are lacking (Davies *et al.*, 2012; Ecklund, James & Lincoln, 2012; Royal Society, 2006). Barriers may include a lack of time, the perception that those who engage are deficient scientists (Royal Society, 2006), and scientists'/researchers' perception of their own communication skills and their perception of the publics' attitudes towards them and their subject matter (Bauer, Allum & Miller, 2007). There is concern that many scientists see the main reason for engaging with the public as the need to «educate» them, rather than to debate, listen and learn as part of a genuine dialogue.

Additionally key facets of research literature, such as language (table 1) (Markic & Childs, 2016), attitudes (Osborne, Simon & Collins, 2003), social theories of learning applied to science and conceptual understanding (Johnstone, 2000), remain problematic in that they are significant issues in the context of wider science education, but can also play a role in effective public engagement.

Therefore, communication of research to/engagement with the public is dependent on the ability of the researcher to share and explain their knowledge using the correct form of communication (Bray, France & Gilbert, 2012). Researchers must endeavour to ensure that they do not present their work in a way, which may appear logical to them, but not to their audience. Johnstone (2000, p. 10), when referring to how we teach school science, has argued that we present science and chemistry in an «apparently» logical way, which while logical to chemists (and those who develop syllabi) is conflicting with what is known about how we learn (the psychological). The following areas are considered to be essential to effective communication/public engagement:

— Knowledge of audience, *e.g.* background.

— Knowledge of context, *e.g.* socio-cultural/political issues.

— Use of appropriate language, *e.g.* emotive, storytelling, dual meanings of words.

— Self-awareness of own scientific values and purpose of communication/engagement activity.

— Issues with understanding of abstract concepts, *e.g.* Piagetian theories.

— Ensuring that there is not an information overload, *e.g.* Johnstone (2006).

— However, Brownell, Price & Steinman (2013) believe that formal training in science communication can improve and promote the way scientists actively communicate their work with a diversity of audiences, including the general public.

*Table 1. Problematic words with everyday meanings and scientific meanings, adapted from Markic, Broggy & Childs (2013)*

| *Word* | *In science* | *Everyday* |
|---|---|---|
| Volume | Space occupied by an object. | Loudness of music, one in a series (*e.g.* books). |
| Crude | Rough measurement, impure substance. | Rude. |
| Transfer | Move from one thing to another. | Football player changing clubs. |
| Complex | Complicated or chemical compound involving metals. | Psychological condition. |
| Model | Scientific description, representation. | Naomi Campbell; a toy. |
| Agent | An active ingredient, a reactant. | James Bond, secret agent. |
| Rate | Speed of a reaction. | Council taxes; cost per minute. |
| Medium | Matter through which waves travel, packing material in chromatography. | Neither large nor small; a psychic. |

**Formal, informal and non-formal learning**

The OECD (2012) defines *formal learning* as always organised and structured, with learning objectives. From the learner's standpoint, it is always intentional: *i.e.* the learner's explicit objective is to gain knowledge, skills and/or competences. *Informal learning* as out-of-school learning that is unstructured and does not follow a specific curriculum, such as a visit to a museum or science exhibit. It is never intentional from the learner's standpoint. Often it is referred to as *learning by experience* or just as *experience*. Non-formal learning is also out-of-school learning, but has a specific structure and is connected to some kind of a syllabus or curriculum. Coll, Gilbert, Pilot & Streller (2013) note that despite the terms *informal* and *non-formal science education* being both officially defined and widely used, they often are not coherently applied. The terms are frequently used to describe any events that take place outside of school or even outside of the regular classes. Both informal and non-formal educational settings offer broad possibilities for science education, communication and public engagement (Garner, Hayes & Eilks, 2014). If one of our goals is to enhance attitudes, understanding and literacy, then learning is always intentional from the perspective of the organiser/teacher. Outreach and public engagement opportunities frequently fall within one of these definitions, but just as frequently they do not fall into any!

As previous discussed, one way of making science accessible to the public and providing opportunities to engage with it is through public engagement events, which may be formal, informal or non-formal, where scientists are in a position to interact with public audiences (Besley & Tanner, 2011).

**An opportunity?**

Outreach and public engagement activities provide significant opportunities for further research into perception of, understanding of, attitudes towards and self-concept in informal, non-formal and formal education settings. Outreach and public engagement activities include initiatives such as lecturing in schools, giving interviews to journalises for media (newspapers, magazines, radio, television), writing popular science books, blogging about research, writing oneself for newspapers or magazines, participating in public debates or *café scientifique*/Pint of Science (fig. 3), collaborating with non-governmental organisations (NGOs), participating in workshops for the public or schools and more (Bauer & Jensen, 2011). This paper acknowledges that there have been very few studies assessing the level of outreach and public engagement activities among scientists (Bauer & Jensen, 2011), or whether these activities can have any significant educational impact, and if so how can we learn from it, given that there is no single satisfactory definition of *outreach* and *public engagement*.

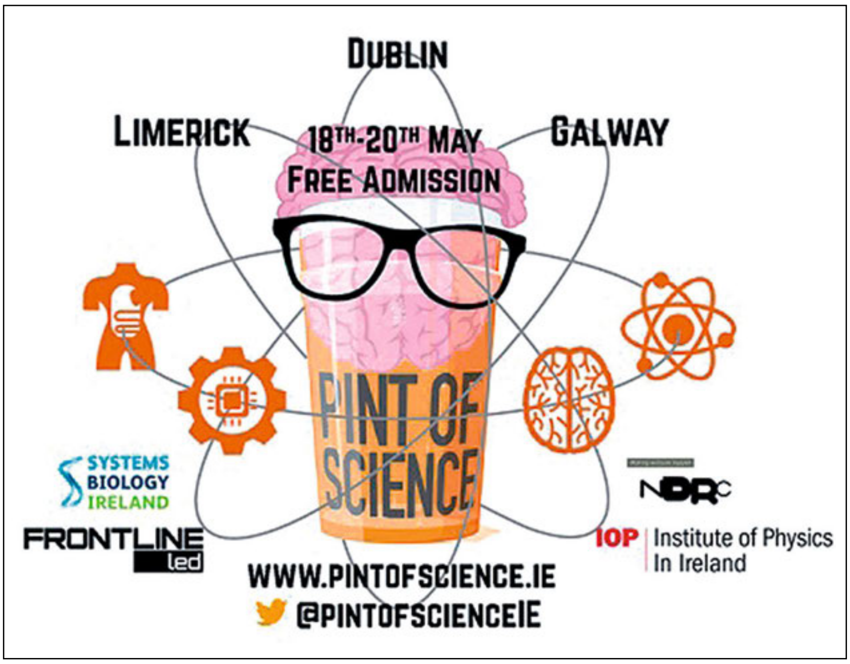


*Figure 3. Pint of Science in Limerick, Ireland.*

**Sample results**

The author works for a research centre in Ireland, the Synthesis and Solid State Pharmaceutical Centre, funded by Science Foundation Ireland. Her role in this centre is to develop and deliver outreach and public engagement programmes. This should be done in partnership with the scientists who work in the centre, and should highlight (where possible) and reflect the research being carried out in the research centre which is associated with pharmaceutical manufacturing, an area of vital importance and significance to the Irish economy. Some sample results will be presented in this section, illustrating specific outreach and public engagement pieces of work which were carried out with a specific school audience in mind.


*Figure 4. Cover of «Innovation in Medicine» module.*

***«Innovation in Medicine»***

This outreach and public engagement project utilised a number of educational approaches, incorporating teaching and

«Innovation in Medicine» outreach and public engagement project utilised a number of educational approaches, incorporating teaching and learning through a contextualised module with dual informal and formal teaching approaches

learning through a contextualised module with dual informal and formal teaching approaches. Previous work carried out into the area of informal learning and Transition Year Science (Garner, Hayes & Eilks, 2014; Hayes & Childs, 2013) indicated the value of context-based, relevant and authentic materials, with a focus on career orientation and mixed teaching and learning methodologies. This led to the development of a module entitled «Innovation in Medicine» aimed at pupils (aged 15-16) and teachers in post-primary education (fig. 4). The project received funding from Science Foundation Ireland, and the module was developed in partnership with teachers through the development of a community of learners. In total, thirteen teachers and two pre-service teachers were involved in module development, which took place over one year with two face-to-face workshops.

An initial pilot study was carried out, utilising Kind, Jones & Barmby (2007): «Attitudes towards science measures» (used with permission from Patrick Barmby). The pilot was carried out with a class of twenty-two pupils and included a focus group with a sub-cohort of this class. Pilot results indicated that pupils experienced:

— Increase in attitudes towards science outside of school $p < 0.05$.

— Increase in positive attitudes towards future participation in science $p < 0.05$.

— The benefits of science are not seen to be greater than the harmful effects.

A further pilot was undertaken involving five schools and included pre- and post-pupil questionnaires (n = 67) and teacher surveys (n = 5). Results from this subsequent pilot are illustrated in table 2.

*Table 2. Overview of results from «Medicines in my life»*

| *Category* | *Results* | *Significance* |
|---|---|---|
| Module enhanced female pupils attitudes towards science more than males | Male 40 % Female 75 % | $p < 0.05$ |
| Females enjoyed the science more than males | Male 75 % Female 100 % | $p < 0.05$ |
| Student attitudes to learning science in school | 33 % to 62 % | $p < 0.05$ |
| Students gained more insight into STEM careers | 52 % to 81 % | $p < 0.05$ |
| Module was relevant to their lives | 83 % | |
| Module encouraged students to continue studying science | 75 % | |
| Teachers rethinking their pedagogical approach | 100 % | |

Further outreach and public engagement activities from the Synthesis and Solid State Pharmaceutical Centre have been in the region of over three hundred in the period from September 2013 to January 2017. Outreach and public engagement activities have led to direct engagement with over 100,000 individuals, and indirect engagement has been in the region of two million through media interactions.

***SSPC science show***

This science show was developed by Dr. Elaine Regan and Dr. Peter E. Childs at the University of Limerick as an outreach initiative to schools (Regan, 2009). The show was originally developed as an in-school promotional intervention aimed at increasing enrolments in chemistry in post-primary schools. Regan's (2009) study indicated that the show may aid in developing pupils' interest in chemistry and causing pupils to consider their career options in the short term, but not in the long term (Regan, 2005). However, in light of the evidence around pupils' conceptions work by Regan (2009) indicates that shows such as these may act as a means of changing subject choice behaviour, if these types of shows and demonstrations are incorporated into typical classroom pedagogy. Therefore, the show has evolved, with it no longer being referred to as a *chemical magic show*, and the TEMI (Broggy *et al.*, 2015) approach has been incorporated into the demonstrations, with an important focus being placed on questioning and inquiry-based learning. Further evaluation of the show is required, but recent work carried out by the author indicates that this approach can offer opportunities for the acquisition or development of scientific knowledge.

## Conclusions

There are significant research opportunities across utilising outreach and public engagement initiatives across the formal, informal and non-formal sectors, examining whether these activities can have any significant educational impact, and if so how can we learn from it, given that there is no single satisfactory definition of *outreach* and *public engagement*. Additionally, outreach and public engagement activities can be informed by best practice in science education and public understanding of science research. However, in order to achieve these goals, the needs to be more integration and collaboration of independent efforts, and a clear pathway for the development of robust evaluation practices.

## References


ARCHER, L. (2013). *Young people's science and career aspirations, age 10-14*. London: King's College.

BAUER, M. W. (2008). «Paradigm change for science communication: commercial science needs a critical public». In: CHENG, D.; CLAESSENS, M.; GASCOIGNE, T.; METCALFE, J.; SCHIELE, B.; SHI, S. (ed.). *Communicating science in social contexts*. Dordrecht: Springer, p. 7-25.

BAUER, M. W.; ALLUM, N.; MILLER, S. (2007). «What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda». *Public Understanding of Science*, vol. 16, No. 1, p. 79-95.

BAUER, M. W.; JENSEN, P. (2011). «The mobilization of scientists for public engagement». *Public Understanding of Science*, vol. 20, No. 1, p. 3-11.

BESLEY, C. J.; TANNER, H. A. (2011). «What science communication scholars think about training scientists to communicate». *Science Communication*, vol. 33, No. 2, p. 239-263.

BRAY, B.; FRANCE, B.; GILBERT, K. J. (2012). «Identifying the essential elements of effective science communication: what do the experts say?». *International Journal of Science Education: Part B*, vol. 2, No. 1, p. 23-41.

BROGGY, J.; CHILDS, P.; MCCORMACK, O.; MCMANUS, B.; O'DWYER, A. (2015). «Involving Irish Pre-Service Science Teachers in the TEMI Project». In: *New perspectives in science education*. $4^{th}$ ed. Florence: Pixel, pp.202-207.

BROWNELL, S. E.; PRICE, J. V.; STEINMAN, L. (2013). «Science communication to the general public: why we need to teach undergraduate and graduate students this skill as part of their formal scientific training». *Journal of Undergraduate Neuroscience Education*, vol. 12, p. E6-E10.

CHRISTIDOU, V. (2010). «Greek students' images of scientific researchers». *Journal of Science Communication*, vol. 9, No. 3, p. 1-12, A01.

CHRISTIDOU, V.; KOUVATAS, A. (2013). «Visual self-images of scientists and science in Greece». *Public Understanding of Science*, vol. 22, No. 1, p. 91-109.

CLEAVES, A. (2005). «The formation of science choices in secondary school». *International Journal of Science Education*, vol. 27, No. 4, p. 471-486.

COLL, R. K.; GILBERT, J. K.; PILOT, A.; STRELLER, S. (2013). «How to benefit from the informal and interdisciplinary dimension of chemistry in teaching?». In: EILKS, I.; HOFSTEIN, A. (ed.). *Teaching chemistry: A studybook*. Rotterdam: Sense, p. 241-268.

DAVIES, A.; MBETE, B.; FEGAN, G.; MOLYNEUX, S.; KINYANJUI, S. (2012). «Seeing "with my own eyes": strengthening interactions between researches and schools». *IDS Bulletin*, vol. 43, No. 5, p. 61-67.

DAVIES, S. R. (2008). «Constructing communication: talking to scientists about talking science». *Science Communication*, vol. 29, No. 4, p. 413-434.

DILLON, J. (2009). «On scientific literacy and curriculum reform». *International Journal of Environmental and Science Education*, vol. 4, No. 3, p. 201-213.

DUSCHL, R. A.; SCHWEINGRUBER, H. A.; SHOUSE, A. W. (ed.) (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington: The National Academies Press.

ECKLUND, E. H.; JAMES, S. A.; LINCOLN, A. E. (2012). «How academic biologists and physicists view science outreach». *PLoS ONE*, vol. 7, No. 5, p. 1-5, e36240.

EUROPEAN COMMISSION (2004). *Report by the High Level Group on increasing human resources for science and technology in Europe*. Luxembourg: Office for Official Publications of the European Communities.

— (2008). *Public engagement in science* [online]: *Report of the Science in Society session*. Brussels: European Commission. <http://ec.europa.eu/research/science-society/document_library/pdf_06/public-engagement-081002_en.pdf> [Last accessed: 28 July 2016].

GARNER, N.; HAYES, S. M.; EILKS, I. (2014). «Linking formal and non-formal learning in science education: a reflection from

two cases in Ireland and Germany». *Sisyphus Journal of Education*, vol. 2, No. 2, p. 10-31.
Johnstone, A. H. (2000). «Teaching of chemistry-logical or psychological». *Chemistry Education Research and Practice in Europe*, vol. 1, No. 1, p. 9-15.
— (2006). «Chemical education research in Glasgow in perspective». *Chemistry Education Research and Practice*, vol. 7, No. 2, p. 49-63.
— (2010). «You can't get there from here». *Journal of Chemical Education*, vol. 87, No. 1, p. 22-29.
Kind, P.; Jones, K.; Barmby, P. (2007). «Developing attitudes towards science measures». *International Journal of Science Education*, vol. 29, No. 7, p. 871-893.
Markic, S.; Broggy, J.; Childs, P. (2013). «How to deal with linguistic issues in chemistry classes». In: Eilks, I.; Hofstein, A. (ed.). *Teaching chemistry: A studybook*. Rotterdam: Sense, p. 127-152.
Markic, S.; Childs, P. (2016). «Language and the teaching and learning of chemistry». *Chemistry Education Research and Practice*, vol. 17, No. 3, p. 434-438.
Mathews, D. J. H.; Kalfoglou, A.; Hudson, K. (2005). «Geneticists' views on science policy formation and public outreach». *American Journal of Medical Genetics*, 137A, p. 161-169.
Millar, R.; Osborne, J. (1998). *Beyond 2000: Science education for the future*. London: King's College.
Mulder, H. A. J.; Longnecker, N.; Davis, L. S. (2008). «The state of science communication programs at universities around the world». *Science Communication*, vol. 30, No. 2, p. 277-287.
National Academies (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington: The National Academies Press.
National Research Council (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington: The National Academies Press.
— (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington: The National Academies Press.
OECD (2007). *Science competencies for tomorrow's world*. Paris: OECD Publications.
— (2012). *Higher education and adult learning* [online]: *Recognition of non-formal and informal learning*. Paris: OECD Publications. <http://www.oecd.org/edu/skills-beyond-school/recognitionofnon-formalandinformallearning-home.htm> [Last accessed: 15 September 2017].
Osborne, J.; Simon, S.; Collins, S. (2003). «Attitudes towards science: a review of the literature and its implications». *International Journal of Science Education*, vol. 25, No. 9, p. 1049-1079.
Regan, E. M. (2005). *Irish student and teacher perspectives on enrolments, subject choice, attitudes towards science and the promotion of Leaving Certificate Chemistry: The design, implementation and evaluation of an in-school promotional intervention*. Doctoral thesis. Limerick: University of Limerick.
— (2009). «"I liked the experiment because there aren't too many people who come into school to burn money": promoting participation in the sciences with chemical magic». *Improving Schools*, vol. 21, No. 3, p. 261-276.
*Research excellence framework* [online] (2014). Bristol: Higher Education Funding Council for England. <http://www.ref.ac.uk/results/intro/> [Last accessed: 5 June 2015].
Roth, W.-M.; Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York: Routledge.
Royal Society (2006). *Factors affecting science communication: A survey of scientists and engineers*. London: Royal Society: RCUK: Wellcome Trust.
RRI (2013). *Options for strengthening responsible research and innovation*. Brussels: European Commission.
Sanden, M. C. A. van der; Meijman, F. J. (2008). «Dialogue guides awareness and understanding of science: an essay on different goals of dialogue leading to different science communication approaches». *Public Understanding of Science*, vol. 17, No. 1, p. 89-103.
Science Foundation Ireland (2015). *Annual Plan 2015*. Dublin: Science Foundation Ireland.

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