Grant Agreement No: 321488

SYN-ENERGENE

Synthetic Biology – Engaging in Responsible Governance of New and Emerging Science and Technology in Responsible Governance of the Science and Society Relationship

Deliverable

D2.1 State of the art review on Socio-scientific learning in schools

<u>Due date of deliverable:</u>	31st January 2014
<u>Completion date of deliverable:</u>	31st March 2014
Start date of SYN-ENERGENE project:	1st July 2013
Project duration:	48 months
Version:	[V1.1]
File name:	[SYN-ENERGENE_State-of-the-art review_D2.1_UU]
<u>Responsible partner for deliverable:</u>	**UU**
Contributing partners:	
Project Coordinator name:	Christopher Coenen
Project Coordinator organisation name:	Karlsruhe Institute of Technology

The SYN-ENERGENE Project is funded by the European Commission within the 7th Framework Programme.

Universiteit Utrecht

Freudenthal Institute
for Science and Mathematics Education

Document Info

Main Editor(s)	A.J. Waarlo, a.j.waarlo@uu.nl
Contributor(s)	-
Reviewer(s)	-
This document should be referenced as	Waarlo, A.J., (2014). *Enhancing Socio-Scientific Issues-based Learning in Schools*, D2.1 SYN-ENERGENE, co-funded by the European Commission under the 7th Framework Programme, Karlsruhe, Germany / Utrecht University, Freudenthal Institute for science and mathematics education (NL).

Ver-sion	**Issue Date**	**Distribution**	**Changes made/ comments**	**Draft (D) vs. final version (F)**
V1.1				

Dissemination level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (excluding the Commission Services)	

Enhancing Socio-Scientific Issues-based Learning in Schools

Arend Jan Waarlo

Utrecht University
Freudenthal Institute for science and mathematics education [FIsme]

Table of contents

Foreword

Over the last years the Freudenthal Institute for science and mathematics education [FIsme] at Utrecht University was involved in various Dutch projects on genomics education and communication for citizenship.[1] Before starting new activities in the field of synthetic biology, it would be wise to take some time for reflection and to learn from past experiences. The multidisciplinary network of SYNENERGENE has much in common with the network of the former Dutch *Centre for Society and Genomics*. One important experience was that we learned a lot from genomics, humanities and social science researchers and from science communicators which was helpful in updating science education in schools. On the other hand it stroke us that many project partners were not well-informed about what's going on in schools and overestimated the uptake of innovative additional educational materials and activities developed by outsiders.[2] Teachers play a crucial role in reaching students. They often feel overburdened or less confident about facilitating classroom discussions. Or they hold different task perceptions as to teaching about values.[3]

The outcomes of the reflection process are reported in this Working Paper. It is not only experience-based, but also builds on input from research literature and key informants. Central to education and communication activities in SYNENERGENE is empowering and facilitating various publics for informed opinion-forming and decision-making on controversial issues arising from applications and implications of synthetic biology. In the domain of science education this is called *Socio-Scientific Issues-based learning*, an important pillar of citizenship education and potentially an educational operationalization of EU's Responsible Research and Innovation concept.

This Working Paper is meant to inform participants of the *WP2 – Knowledge sharing and mutual learning training workshop*, Brussels, 8th-9th April 2014 about needs and wants of educators and communicators. Therefore it concludes with an invitation to SYNENERGENE partners with different expertise to answer some urgent questions. In addition, the Working Paper provides background information for the workshop session on framing and dialogical inquiry. Any feedback on this paper will be welcomed so as to make it as usable as possible before including (parts of) it in the toolkit for public engagement and participation.

FIsme is leader of another FP7 project entitled *Promoting Attainment of Responsible Research and Innovation in Science Education* (Project acronym: PARRISE), which has some common ground with SYNENERGENE. We will be happy to serve as a linking pin between the two projects.

---

[1] *CSG Next 2008-2013: Harvesting results & Preparing for the future* http://www.society-lifesciences.nl/fileadmin/user_upload/docs/Publicaties_PDFs/Rapporten/CSG-next_2008-2013_web.pdf

[2] A PhD study on adoption and implementation of AIDS education in Dutch secondary schools revealed that 70% of the targeted teachers had heard of additional educational material, 50% had seen it, 30% had acquired it, 15% used it, but only 5% used it as intended!

[3] Corrigan, D., Dillon, J. & Gunstone, R. (Eds.) (2007). *The Re-Emergence of Values in Science Education.* Rotterdam / Taipei: Sense Publishers.

Aims of the Working Paper

- To make a SWOT analysis of the shaping, implementation, processes and outcomes of socio-scientific issues-based learning in classrooms and to further articulate the rhetoric-practice gap
- To learn from past experiences and research and to inform the design of educational materials and activities for students and teachers aimed at public engagement and participation in the development of synthetic biology
- To share the gained knowledge with SYNENERGENE partners and to identify common ground with Ecsite partners so as to enable fine-tuning of activities in formal and informal learning environments based on a shared vocabulary and mutual understanding
- To get feedback and input from partners with various backgrounds to further elaborate this Working Paper for inclusion of relevant parts in the toolkit and to make it available to a wider audience
- To provide a context and rationale for the workshop session on frame reflection

Socio-Scientific Issues-based (SSI-based) education

Advancements in science and technology have an impact on individuals and society and vice versa. There are no simple solutions to complex problems raised (SSIs), only sensible choices. Socio-scientific issues[4]

- have a basis in science, frequently at the frontiers of scientific knowledge;
- involve forming opinions, making choices at personal or societal level;
- are frequently media-reported, with attendant issues of presentation based on the purposes of the communicator;
- deal with incomplete information because of conflicting/incomplete scientific evidence, and inevitably incomplete reporting;
- address local, national and global dimensions with attendant political and societal frameworks;
- involve some cost-benefit analysis in which risk interacts with values;
- may involve consideration of sustainable development;
- involve values and ethical reasoning;
- may require some understanding of probability and risk;
- are frequently topical with a transient life.

Preparing citizens for participation in socio-scientific discourses should start in their school years. However, many students don't like science due to lack of perceived relevance to everyday life. The use of SSIs in science classroom should not only make science content attractive for students, but also promote functional scientific and technological literacy.[5] [6] The latter requires an understanding of the nature of science and technology and of the skills necessary to think scientifically,

---

[4] Ratcliffe, M. & Grace, M. (2003). *Science education for citizenship. Teaching socio-scientific issues.* Maidenhead / Philadelphia: Open University Press, pp. 2-3.

[5] Zeidler, D.L. & Kahn, S. (2014). *It's Debatable! Using Socioscientific Issues to Develop Scientific Literacy K-12*. Arlington, Virginia: NSTA Press, National Science Teachers Association.

[6] Vries, M.J. (2012). International Curriculum Requirements for Making Connections in Science and Technology Education. In B.J. France and V.J. Compton (eds.), *Bringing Communities Together: Connecting learners with scientists or technologists.* Rotterdam: Sense Publishers.

technologically and ethically about controversial issues. SSIs have a knowledge and a values component and require informed decision-making. Due to pluralism in a democratic society different normative perspectives should be included and debated. The teacher as facilitator of this process is crucial; students might be at risk of indoctrination or hidden persuasion by their teacher. In short, SSI-based learning is at the heart of science and technology education for citizenship.[7] However, a rhetoric-practice gap exists: policy makers and scholars run ahead on practitioners and the latter may not practice what they preach. [8]

To further explore the rhetoric-practice gap a framework for SSI-based education will be used as a normative tool. This framework (Table 1), which should also inform design and implementation of SSI-based education on synthetic biology, is based on international experiences with and reflection on the use of socio-scientific issues in the classroom.[9] . The framework consists of design elements, learner experiences, classroom environment and teacher attributes. Design elements and learner experiences are central to SSI-based education. Classroom environment and teacher attributes play a role in shaping the implementation of the former two elements.

SWOT analysis

A SWOT analysis on SSI-based education, in general and related to synthetic biology (SynBio), was carried out to support the writing of this Working Paper (Fig. 1). A SWOT analysis aims at identifying helpful (strengths and opportunities) and harmful (weaknesses and threats) characteristics and elements in achieving an objective. Strengths and weaknesses have internal origin, opportunities and threats are of external origin. The SWOT analysis was based on critical reflection on ample personal experiences gained in Dutch 'Genomics Education for Citizenship' projects[10], on reviewing selected socio-scientific key publications, and on interviewing five informants.[11] The latter are experts in technology education, emotional deliberation, techno-moral imagination, frame reflection, and facilitating and studying public dialogue and deliberation respectively. Although this Working Paper is informed by various sources, it will certainly have a Dutch perspective and be subjectively biased. However, it is meant to share ideas and to elicit feedback during the *WP2 – Knowledge Sharing and Mutual Learning Training Workshop* (Brussels, 8th -9th April 2014) before including a revised and intersubjective version (of valuable parts) in the toolkit to be developed in the project. Ecsite

---

[7] Ratcliffe, M. & Grace, M. (2003). *Science education for citizenship. Teaching socio-scientific issues.* Maidenhead / Philadelphia: Open University Press.

[8] Levinson, R. & Turner, S. (2001). *Valuable lessons. Engaging with the social context of science in schools. Recommendations and summary of research findings.* London: The Trustee of the Welcome Trust. http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtd003446.pdf

[9] Sadler, T.D. (2011). Socio-scientific Issues-based Education: What We Know About Science Education in the Context of SSI. In Sadler, T.D., *Socio-scientific Issues in the Classroom. Teaching, Learning and Research*. Dordrecht, Heidelberg, London, New York: Springer Science+Business Media, pp. 355-369.

[10] *CSG Next 2008-2013: Harvesting results & Preparing for the future* http://www.society-lifesciences.nl/fileadmin/user_upload/docs/Publicaties_PDFs/Rapporten/CSG-next_2008-2013_web.pdf

[11] Prof.dr. Marc de Vries & Prof.dr. Sabine Roeser (both at Delft University of Technology), Prof.dr. Tsjalling Swierstra (Maastricht University), Dr. Frank Kupper (VU University Amsterdam) and drs. K. Dortmans (Radboud University Nijmegen).

partners who are planning activities for schools might have special interest in what is going on in schools so as to attune as much as possible.

Table 1. Essential and recommended guidelines for SSI-based education.

Design Elements	
Essential	*Recommended*
Build instruction around a compelling issue	Use media to connect classroom activities to the 'real world'
Present the issue first Provide scaffolding for higher-order practices (e.g. argumentation, reasoning and decision-making)	Use technology to facilitate student learning experiences
Provide a culminating experience	
Learning Experiences	
Engage in reasoning, argumentation, decision-making and/or position taking	Confront the ethical dimensions of the issue being considered[12]
Confront the scientific ideas and theories related to the issue being considered	Consider nature of science themes associated with the issue
Collect and/or analyse scientific data related to the issue being considered	
Negotiate the social dimensions of the issue being considered	
Classroom Environment	
High expectation for student participation	
Collaborative and interactive	
Students and teachers demonstrate respect for one another	
Students and teachers feel safe within the environment	
Teacher Attributes	
Familiar with issues being considered a. Knowledgeable about science content related to the issue b. Aware of the social considerations associated with the issue	
Honest about knowledge limitations	
Willing to deal with uncertainties in the classroom	
Willing to position self as a knowledge contributor rather than sole authority	

[12] In our view, ethical inquiry is an essential component of SSI-based education.

Before presenting the outcome of the SWOT-analysis, first some more words about genomics education for citizenship. During the last decade FIsme participated in Dutch genomics-related education and communication activities, starting with developing and implementing mobile DNA labs[13], followed by rethinking science curricula in the genomics era[14] and concluded with consensus building on genetics literacy needed by a 21st century citizen (in preparation). The DNA labs were successful in providing new science content and skills in different application contexts, but underperformed in discussing the social and moral implications. In response to that more emphasis was put on scientific citizenship education and informed decision-making.[15] Many science teachers lack the support and confidence to address value-laden issues in their classrooms, so we also started research and in-service education to empower and facilitate them.[16] [17] [18]

Below the SWOT-analysis will be discussed through focussing on some unifying themes across the strengths, weaknesses, opportunities and threats. After all, weaknesses and threats might be addressed by looking for solutions through taking advantage of strengths and opportunities. A major cross-cutting theme is the rhetoric-practice gap. SSIs have a knowledge-component and a values-component. This Working Paper is mainly about the tricky values-component. This is not to say that the knowledge component of synthetic biology is a piece of cake. Quite the contrary!

Rhetoric-practice gap

The contents of policy documents and scholarly articles in the field of science education and communication are often far ahead of practice. Discrepancies between the policy discourse, the content of educational materials and the actual teaching practices can be easily demonstrated. The rhetoric-practice gap can be mapped by using descriptors of the dominant but disputed transmission paradigm and the alternative transformation paradigm in education and communication (Table 2).[19]

---

[13] Van Mil, M. H. W., Boerwinkel, D. J., Buizer-Voskamp, J. E., Speksnijder, A., & Waarlo, A. J. (2010). Genomics education in practice: Evaluation of a mobile lab design. *Biochemistry and Molecular Biology Education, 38*(4), 224-229.

[14] Boerwinkel, D. J. & Waarlo, A. J. (Eds.) (2009). *Rethinking Science Curricula in the Genomics Era, 4-5 December 2008, Utrecht, The Netherlands.* Utrecht: Utrecht University, Freudenthal Institute for Science and Mathematics Education (FIsme Scientific Library, No. 62). http://dspace.library.uu.nl/bitstream/handle/1874/37105/Rethinking%20science%20curricula%20in%20the%20genomics%20era.pdf?sequence=1

[15] Boerwinkel, D. J. & Waarlo, A. J. (Eds.) (2011). *Genomics education for decision-making. Proceedings of the Second Invitational Workshop on Genomics Education, 2-3 December 2010, Utrecht, The Netherlands.* Utrecht: Utrecht University, Freudenthal Institute for Science and Mathematics Education (FIsme Scientific Library, No. 67). http://dspace.library.uu.nl/bitstream/handle/1874/207840/Genomics%20Education%20for%20Decision%20Making.pdf?sequence=1

[16] Van der Zande, P.A.M. (2011). *Learners in dialogue. Teacher Expertise and Learning in the Context of Genetic Testing.* Utrecht: Utrecht University (PhD thesis). http://dspace.library.uu.nl/bitstream/handle/1874/205394/zande.pdf?sequence=2

[17] Boerwinkel, D.J., Knippels, M.C.P.J. and Waarlo, A.J. (2011). Raising awareness of pre-symptomatic genetic testing, *Journal of Biological Education*, *45*, 213-221.

[18] Boerwinkel, D. J., Swierstra, T. & Waarlo, A. J. (2014). Reframing and articulating socio-scientific classroom discourses on genetic testing from an STS perspective. *Science & Education, 23*, 485–507.

[19] Sterling, S. (2011) *Sustainable Education. Re-visioning Learning and Change.* Green Books on behalf of The Schumacher Society, p. 38.

Strengths	Weaknesses
• Exemplifying the intertwining of science and technology in society (research and design go hand in hand; techno-sciences) • Science and technology education for citizenship (educational operationalization of EU's Responsible Research and Innovation (RRI) • Relevant education: contextualized and personalized science and technology • Evidence for outcomes in terms of raising interest and motivation; gains in knowledge, reflective judgment and argumentation[20]	• Conceptual and normative complexity and uncertainty of emerging techno-sciences[21] • Teachers' and students' misconceptions about the nature of science and technology and how they are interrelated (research and design) • One-sided conception of 'informative opinion-forming & decision-making' (limited to science) • Supposed lack of feasible hands-on activities • The use of mechanistic metaphors[22] • Role of instructional metaphors and analogies not self-evident[23] • Undervaluing intuitions and emotions as a source of knowledge • Poor elicitation of assumptions, beliefs, values underlying voiced opinions • Teachers' poor self-confidence and competence in dealing with (the values-component of) controversial issues • Restricted knowledge of repertoire of teacher's roles in handling controversial issues • Mixing up dialogue and debate • Learning beyond awareness-raising
Opportunities	**Threats**
• Drawing on knowledge base of science and technology studies; knowledge sharing and mutual learning workshop • Best practices on related topics, e.g. genomics and nanotechnology • Pedagogical models for ethical inquiry into socio-scientific issues • Connecting to on-going transformative innovations in education • Related EU projects (e.g. COREFLECT, PARRISE) • Cross-curricular approach to teaching • Synergy of formal and informal learning activities; fine-tuning of learning in schools and in science centres and museums	• Supposed non-availability of realistic and appealing applications for everyday life (in short term) • Hopes and hypes: utopian promises • No critical reflection on limitations in tinkering with (the machinery of) life; need for revision of ethical categories • Framing based on previous debates about other novel technologies resulting in fruitless discussions • Technological and populist pitfall • Dominance of positivistic paradigm; disrespect for pluralism • Time and curricular constraints • Dominance of transmission education • Lack of common language

Fig. 1. SWOT-analysis of socio-scientific issue-based learning to inform educational design and teacher preparation in SYNENERGENE.

[20] Sadler, T.D. & Dawson, V. (2012) Socio-scientific Issues in Science Education: Contexts for the Promotion of Key Learning Outcomes. In Fraser, B.J. et al. (Eds.). *Second International Handbook of Science Education*. Springer International Handbooks of Education 24. Dordrecht: Springer Science+Business, pp. 799-809.
[21] Ravetz. J. (2006) *The no-nonsense guide to science*. New Internationalist
[22] Hellsten, I. & Nerlich, B. (2011). Synthetic biology: building the language for a new science brick by metaphorical brick. *New Genetics in Society, 30:4*, 375-379.
[23] Niebert, K., Marsch, S. & Treagust, D.F. (2012). Understanding Needs Embodiment: A Theory-Guided Reanalysis of the Role of Metaphors and Analogies in Understanding Science. *Science Education, 96:5*, 849-877.

Table 2. The differences between transmission and transformation in education at practice and policy level. The descriptors of the two paradigms are helpful in articulating the rhetoric-practice gap.

Transmission paradigm	Transformation paradigm
Instructive practice	**Constructive practice**
Teaching	Learning (iterative)
Training	Education
Factual knowledge and skills	Conceptual understanding and capacity building
Information – 'one size fits all'	Local and/or appropriate knowledge important
Communication of 'message'	Construction of meaning
'Problem-solving'- time-bound	'Problem-reframing' and iterative change over time
First order change	First *and* second order change[24]
Product oriented	Process oriented
Interested in behavioural change	Interested in mutual transformation
Control kept at centre	Local ownership
Rigid	Responsive and dynamic
Imposed policy	**Participative policy**
Top-down	Bottom-up (often)
Directed hierarchy	Democratic networks
Expert-led	Everyone may be an expert
Pre-determined outcomes	Open-ended enquiry
Externally inspected & evaluated	Internally evaluated through iterative process, *plus* external support
Time-bound goals	On-going process
Language of deficit and managerialism	Language of appreciation and cooperation

The rhetoric-practice gap can be further articulated by applying the so-called levels of representations used in curriculum studies.[25] The *intended* curriculum is the outcome of policy making, design and development. The *implemented* curriculum refers to the actual teaching and learning process. The *attained* curriculum describes the actual learning outcomes. At every level implicit or explicit interpretations are made. These 'translations' can easily lead to derailments and frustrate intended innovations. Therefore they should be explicitly discussed amongst those involved in developing, implementing and evaluating activities and tools for public engagement and participation. Additional in-service education of teachers, e.g. through starting a teacher community for learning to teach SSIs[26] will be helpful in appropriating the innovation.

[24] 'First Order Learning' is based on the premise that learning comes from observing an action and assessing the result. 'Second order learning' is more reflective and includes an understanding of the relationship between action and outcome.
[25] Van den Akker, J. (2004). Curriculum perspectives: an introduction. In J. van den Akker, W. Kuiper & U. Hameyer (Eds.), *Curriculum Landscapes and Trends*. Dordrecht: Kluwer Academic Publishers, pp. 1-10.
[26] Van der Zande, P.A.M. (2011). *Learners in dialogue. Teacher Expertise and Learning in the Context of Genetic Testing.* Utrecht: Utrecht University (PhD thesis: chapter 5).

To keep in mind: *it will be difficult to bridge the rhetoric-practice gap, that is connected with a paradigm shift, but progress can be made by setting realistic goals and carefully monitoring the translation process from ideal to practice at different levels. The descriptors of the transmission and transformation paradigm can be helpful in creating a common language for the necessary collaboration of educational designers and practitioners.*

Learning theoretical perspectives[27] [28]

Informed opinion-forming and decision-making

Central to SSI-based learning is informed opinion-forming and decision-making, which requires active participation in dialogue; taking, justifying and interrogating positions in different societal dilemmas; inquiry; using underpinning scientific evidence; and scrutinizing science-related knowledge claims. In addition, self-knowledge and societal knowledge should inform the opinion-forming and decision-making process as well so as to support personalizing and contextualizing SSIs. Personal and societal knowledge will have a strong values-component. So ill-defined, value-laden and multidisciplinary SSIs appeal to various types of learning: acquiring knowledge, skills and attitudes.

Constructivism and situated learning

SSI-based learning corresponds with the transformation paradigm of education characterized by constructive practice. *Constructivism* emphasizes the active role of the learner in building understanding and making sense of information. Knowing and learning are situated in social practice. The *situated learning approach* connects to social-cultural theory by assuming that humans develop through participation in social cultural practices, e.g. authentic or democratic classroom practices (doing democracy). The authentic practice is prescriptive and frames what is relevant to learn. Social negotiation will be an important aspect of the learning process that relies on collaboration with others and respect for different perspectives. Students must talk and listen to each other and co-construct new meanings and develop intersubjective attitudes, i.e., a commitment to build shared meanings with others by finding common ground and exchanging interpretations. As to the content knowledge relevant to a situation, a problem might be that SynBio is an emergent techno-science with applications and implications in the making. Situated learning emphasizes that the real world is not like studying in school. It is more like an apprenticeship where novices, with the support of an expert guide and model, take on more and more responsibility until they are able to function independently. Situated learning is often described as 'enculturation', or adopting the norms, behaviours, skills, beliefs, language, and attitudes of a particular community. Much of what is learned is specific to the situation in which it is learned, so special attention should be paid to transfer of knowledge and skills from one situation to another.

Problem-based learning and cognitive apprenticeship

SSI-based education is *problem-based learning*: students are confronted with realistic problems that don't necessarily have 'right' answers. A sequence of phases, for example in ethical inquiry, will give hold to teachers and students. With guided participation in real tasks comes participatory appropriation; students appropriate the knowledge, skills and values involved in doing the task. This so-called *cognitive apprenticeship approach* entails the following steps: orientation; modelling; scaffolding; and articulation, reflection and exploration towards the next step.
In the orientation step, the nature of SSIs should be explored and compared to scientific problems students are familiar with. In addition, an overview of the whole 'problem solving' strategy should be

---

[27] Woolfolk, A. (2004). *Educational Psychology*. Boston: Pearson.
[28] Davidsson, E. & Jakobsson (Eds.) (2012). *Understanding Interactions at Science Centers and Museums*. Approaching Sociocultural Perspectives. Rotterdam/Boston/Taipei: Sense Publishers.

given. Next, the teacher demonstrates the performance and students observe. Students start applying the strategy to an SSI in small groups and receive scaffolding, which is gradually faded as the students become more competent and proficient. Students continually are encouraged to articulate their progress through putting into words their understanding of the processes and content being learned, followed by reflecting on their progress. The final step is exploring new ways to apply what they are learning (transfer to new situations). As students learn, they are challenged to master more complex concepts and skills and to perform them in many different settings. The cognitive apprenticeship approach could also be used in empowering teachers for SSI-based education.[29]

To keep in mind: *learning theories are helpful in articulating and structuring the various interwoven learning processes included in SSI-based education. They should be applied in SynBio-related educational design and teacher education.*

Teachers' self-confidence and competence

What did a survey in England and Wales, which sought to uncover how, and in which curriculum subjects, controversies arising from bioscience are tackled in schools and colleges, learn about teacher competencies?[30] Science teachers tend to stick to the facts and shy away from values. Values show what is important to somebody. Moral values are about what somebody thinks is important for own and others' well-being. Norms are agreements between people: you have to follow the rules, which does not apply to values.[31] Science teachers fear for a soft image of their subject. They may have poor knowledge of ethics, fear indoctrination of students and feel uncertain about their pedagogical skills to facilitate opinion-forming debate and dialogue. They tend to distrust news reports about controversial societal issues. And they doubt the testability of learning outcomes. Teachers of humanities or social studies, on the other hand, are quite familiar with values education resources and strategies, but may have poor science knowledge. They are eager to use media reports and they are more familiar with formats and standards to determine the quality of reasoning about controversial issues. They are critical of science teachers doing dialogues during student laboratory work.

These findings correspond with those concerning the Dutch mobile DNA labs, which were successful in providing new science content and skills, but underperformed in discussing the social and moral implications of various genomics applications. In response to that a teacher community for learning to teach the SSI of genetic testing was started and studied.[32] The findings show that the community was useful for expertise development and that this development connects to identity development of teachers in terms of self-understanding. A New Zealand study reported on a project that

[29] Knezic, D., Wubbels, T., Elbers, E. & Hajer, M. (2010). The Socratic Dialogue and Teacher Education. *Teaching and Teacher Education, 26,* 1104-1111.

[30] Levinson, R. & Turner, S. (2001). *Valuable lessons. Engaging with the social context of science in schools. Recommendations and summary of research findings.* London: The Trustee of the Welcome Trust. (www.wellcome.uk)

[31] Veugelers, W. (2011). A Humanist Perspective on Moral Development and Citizenship Education. In: Veugelers, W. (Ed.) *Education and Humanism. Linking Autonomy and Humanity.* Rotterdam / Boston / Taipei: Sense Publishers, pp.9-10.

[32] Van der Zande, P.A.M. (2011). *Learners in dialogue. Teacher Expertise and Learning in the Context of Genetic Testing.* Utrecht: Utrecht University (PhD thesis: chapter 5). http://dspace.library.uu.nl/bitstream/handle/1874/205394/zande.pdf?sequence=2

developed a pedagogical model that scaffolded teachers through a series of stages in exploring a controversial SSI with students and supported them in the use of pedagogical strategies and facilitated ways of ethical thinking.[33] The model actively assisted teachers to improve their practice and confidence in addressing SSI in their classrooms and, in doing so, move towards developing their own and their students' scientific literacy. However, teachers will most likely need further assistance in developing criteria that support them in the assessment of issues where there are no right or wrong answers, but where there is a need to weigh up alternatives and justify decisions, rather than providing fixed answers that have been traditionally assessed in science.
In the Dutch and New Zealand example only science teachers were involved. It might be wise to build heterogeneous communities of teachers to promote interdisciplinary collaboration in developing educational materials and activities and to promote cross-curricular teaching of SSI in schools.[34] In the EU FP7 project with the acronym PARRISE science and citizenship educators co-develop an educational framework for *socio-scientific inquiry based science learning.*

To keep in mind: *realising authentic SSI-based science learning can be done when sufficient curriculum time and space is available. The key issue is confident and competent teachers, who need to be empowered and facilitated. Interdisciplinary collaboration in developing educational materials and activities, and cross-curricular teaching should be considered.*

Public deliberation on socio-scientific issues as model

Simulating public dialogue and debate in classrooms seems a promising approach to empowering youngsters for public engagement and participation in SynBio. So let's have a closer look at the theory and practice of public deliberation.

Facilitator's role
The quality of public dialogue about new and emerging science and technology depends on the quality of the process and content.[35] First of all, the facilitator has an important role in watching discourse rules. Public debates[36] tend to be lively and chaotic events. As to the content the facilitator should encourage participants to explicate unexpressed premises. Critical questions should be asked to test the content and justificatory of every argumentation. Attention should be called to fallacies regarding the outcome of argumentation, such as the slippery slope. Finally, it should be checked that all the issues have been brought up and it should be concluded what (scientific) evidence corroborates certain claims and what is still unknown. In our pluralist societies there will always be moral disagreement. A facilitator should maintain professional objectivity, which might include 'agree to disagree'.

---

[33] Saunders, K.J. & Rennie, L.J. (2013). A Pedagogical Model for Ethical Inquiry into Socioscientific Issues in Science. *Res Sci Educ, 43,* 253-274.
[34] Ratcliffe, M., Harris, R. & McWhirter, J. (2005). Cross-Curricular Collaboration in Teaching Social Aspects of Genetics. In Boersma, K., Goedhart, M., De Jong, O. & Eijkelhof, H. (Eds.) *Research and the Quality of Science Education*. Dordrecht: Springer, pp. 77-88.
[35] Stemerding, D. & Rerimassie, V. (2013) *Discourses on Synthetic Biology in Europe*. The Hague: Rathenau Instituut (working paper 1305).
[36] Public debate and public dialogue are mistakenly often used interchangeably. A dialogue is aimed at inquiry, mutual understanding, collaborative learning and co-construction of new knowledge. A debate is a process of inquiry and advocacy; the strengths and weaknesses of arguments are assessed. Debate tricks may be used and there can be winners and losers.

Science's role
In communicating about science-related policy issues scientists or science communicators can either serve as *honest brokers* or as *issues advocates*[37]. The latter align themselves with a group seeking to advance its interests through policy and politics. They accept the notion that science must be engaged with decision-makers and seek to participate in the decision-making process. Science shops, for example, take this role. They are taking sides in a contested political issue and use their status as scientist to deliver countercheck on request of stakeholders.[38] The honest broker of policy alternatives, on the other hand, engages in decision-making by clarifying and, at times, seeking to expand the scope of choice available to decision-makers. They seek to explicitly integrate scientific knowledge with stakeholder concerns in the form of alternative possible courses of action. The honest broker seems a good role model for the science teacher discussing socio-scientific issues in the classroom.

Code of conduct
From the perspective of framing (see below: Framing and meaning making) ethical imperatives or guiding principles related to public engagement have been formulated.[39] These principles seem applicable to classroom discourses as well and should inform pedagogics of SSI-based learning:

- Emphasizing dialogue and exchange of perspectives rather than top-down communication
- Effective and transparent communication of values; recognizing values-based reasons and not defining debate as matter of 'sound science' or 'driven by science'
- Accuracy in communication: respecting uncertainty and resisting either false balance or exaggeration
- Avoiding to denigrate, stereotype or attack alternative worldviews, including religious worldviews, by defining others as either 'anti-science' or 'pro-science.

Argumentation quality
Democracy entails a deliberative process aimed at "producing reasonable, well-informed opinions in which participants are willing to revise preferences in light of discussion, new information, and claims made by fellow participants".[40] Citizenship education prepares for democracy and should focus on the quality of argumentation and the reasonableness of the deliberation process. Pragma-dialectics offers a framework for analysing argumentative discourse in everyday conversations (pragmatics) and for evaluating its acceptability on the basis of a set of discussion rules[41] that regulate the exchange of views (or standpoints) and the reasons advanced for their support in order to resolve differences of opinion (dialectics).[42] Extended with deontological argumentation and argumentation of justice, pragma-dialectics, which reflects consequentialist argumentation, provides a normative framework for evaluating recurring moral argumentation patterns in public debates. The three argument schemes run as follows:[43]

[37] Pielke, R.A. (2007). *The Honest Broker. Making Sense of Science in Policy and Politics.* Cambridge: Cambridge University Press.
[38] Mulder, H.A.J. & Bok, C.F.M. de (2006). Science shops as university-community interfaces: an interactive approach in science communication. In Cheng, D. e.a. (eds.), *At the human scale. International practices in science communication.* Beijing: Science Press Beijing, pp. 285-304.
[39] Nisbet, M.C. (2009) The ethics of framing science. In Nerlich, B., Elliott, R. & Larson, B. (eds.) (2009) *Communicating biological sciences. Ethical and metaphorical dimensions.* Farnham: Ashgate, p. 70.
[40] Chambers, S. (2003). 'Deliberative Democratic Theory'. *Annual Review of Political Science*, 6, 307-326.
[41] The *relevance rule*, the *unexpressed premise rule,* the *starting point rule,* the *validity rule*, and the *argument scheme rule.*
[42] Van Eemeren, F. H., and Grootendorst, R. (2004). *A Systematic Theory of Argumentation: The Pragma-Dialectical Approach*. Cambridge: Cambridge University Press.
[43] Dortmans, K. and Swierstra, T. (2013). Maintaining reasonableness: How Facilitators Can Improve the Quality of Public Deliberation on New and Emerging Science and Technology. In: Konrad, K. et al. (Eds.), *Shaping Emerging Technologies: Governance, Innovation, Discourse.* Berlin: IOS Press/AKA, Berlin, pp. 21-34.

PRAGMATIC ARGUMENTATION:
Standpoint: Action X should (not) be carried out
Material premise: [because] action X leads to (un)desirable consequence Y
[Connection premise: [and] if action X leads to (un)desirable consequence Y, then it should (not) be carried out]

DEONTOLOGICAL ARGUMENTATION:
Standpoint: Action X should (not) be carried out
Material premise: [because] action X is (not) in accordance with moral principle Y
[Connection premise: [and] if action X is not in accordance with moral princple Y, then it should (not) be carried out]

ARGUMENTATION OF JUSTICE:
Standpoint: Action X should (not) be carried out
Material premise: [because] action X is in itself or in its consequences (un)just
[Connection premise: [and] if action X is in itself or in its consequences (un)just, then it should (not) be carried out]

This normative framework seems helpful to facilitators of public deliberation to improve the quality of argumentation. In addition, it seems promising in shaping and monitoring socio-scientific learning processes in the classroom.
Another framework used in analysing argumentation is Toulmin's Argumentation Pattern[44], which discerns claims, data, warrants and backings. A claim is the conclusion whose merits are to be established. Warrants are the reasons that are used to justify the connection between the data and the conclusion, and backings are the basic assumptions that provide the justification for particular warrants.

Reflective judgment
Argumentation quality also depends on someone's view of knowledge and concept of justification or, in other words, someone's understanding of the nature of science. The development of students' views of knowledge and concepts of justification in SSI-based education can be monitored by using the reflective judgment stages: from pre-reflective and quasi-reflective thinking to reflective thinking.[45] [46] So, science teachers' perceived lack of testability of learning outcomes in SSI-based education seems no longer tenable. To be able to grasp the conceptual and normative complexity and uncertainty of SynBio as an emerging techno-science reflective thinking will be required. However, it cannot be expected that this will be achievable by just offering a few lessons on SynBio.

To keep in mind: *science communication practitioners and scholars have much to say to science educators for use in articulating, shaping, facilitating and assessing classroom discourses through simulating public deliberation. At the same time they make us aware about the complexity of several interwoven learning processes which each need enough time to teach.*

Teaching controversial issues

Discussion and deliberation as process
Teachers are key in facilitating discussion and deliberation of controversial SSIs in the classroom as part of democracy education. Discussion skills urgently need to be taught to promote an open and

[44] Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press. (updated 2003 version available online).
[45] http://www.umich.edu/~refjudg/reflectivejudgmentstages.html
[46] Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing Reflective Judgment through Socioscientific Issues. *Journal of Research in Science Teaching, 46*(1), 74-101.

robust democratic society. Schools are places to encounter pluralism and students have an interest in hearing what their peers (and teachers) think.[47] [48] Participating in discussion involves attending to multiple points of view, being receptive or responsive to opinions other than one's own, and being concerned to develop one's knowledge and understanding. Controversial issues are the area of the curriculum in which teachers can engage students in discussion. From experience it is known that students recall classroom discussions with astonishing specificity. However, spontaneous discussions are rarely successful. Effective discussion requires that students first have the opportunity to prepare, using high-quality material. Topics should be accessible to students for example through empathetic involvement and appealing to immediate intuitions about the rights and wrongs of a practice.[49] [50] Discussions will be fuelled by strong and diverse views among discussants, eliciting passion and disagreement. Teachers play a significant role in facilitating and advancing discussion in terms of providing structure, asking critical questions, and responding to views expressed by students with requests for elaboration and justification. Students have to acquire skills and virtues of discussion by doing: reasonableness, peaceableness and orderliness, truthfulness, freedom, equality and respect for persons.

Impediments to discussion include two sorts of stalling move. For example, the *that's-just-what-I-believe* move and *that's-what-my-religion-says* move. The first move suggests 'what I believe on this matter is just part of who I am'. Any further attack on the opinion in question could be unjustly labelled as a disrespectful attack on identity. The second move shifts an opinion from the domain of public disputation to the domain of personal identity. In addition, it reduces a wide range of ethical disagreements to a single disagreement about the existence of God. A consequence of both moves is that the opinion-forming process gets stuck in just voicing opinions. The technocratic and populist pitfall (i.e. 'ignoring public emotions' and 'do what the public wants'; see below: Emotional deliberation) could also be labelled as stalling moves.

Providing structure

The discussions need to take place within a structure understood by participants and competently moderated to ensure that a range of perspectives are aired. Worksheets and written discussions in small groups can be helpful in providing some relief to teachers who feel hesitant[51]. All students can learn discussion skills and a trained teacher can ensure that each one participates. There are no born talkers and only listeners. Teachers might prefer 'safe' knowledge and 'safe' teaching practices and avoid discussing controversial issues to prevent any criticism of indoctrinating students with their own views. However, they don't necessarily have to share their own views on issues students discuss in class. Teachers may not be familiar with the repertoire of teacher roles appropriate for handling controversial issues.

---

[47] Hand, M. and Levinson, R. (2012). Discussing Controversial Issues in the Classroom. *Educational Philosophy and Theory, 44* (6), 614-629.

[48] Hess, D.A. (2009). *Controversy in the Classroom. The democratic power of discussion*. New York and London: Routledge.

[49] Waarlo, A. J. (1999). Biology students' forming and justifying of opinions on predictive genetic testing. Towards a practicable and effective teaching strategy. In M. Bandiera, S. Caravita, E. Torracca & M. Vicentini, M. (Eds.), *Research in science education in Europe* (pp. 41-48). Dordrecht/Boston/London: Kluwer Academic Publishers.

[50] Boerwinkel, D.J., Knippels, M-C. & Waarlo, A.J. (2011). Raising awareness of pre-symptomatic genetic testing. *Journal of Biological Education*, *45(4)*, 213–221.

[51] Waarlo, A. J. (1999). Biology students' forming and justifying of opinions on predictive genetic testing. Towards a practicable and effective teaching strategy. In M. Bandiera, S. Caravita, E. Torracca & M. Vicentini, M. (Eds.), *Research in science education in Europe.* Dordrecht/Boston/London: Kluwer Academic Publishers, pp. 41-48.

Facts and values
There is a perception amongst many science teachers that science education is about the delivery of facts, and that science is value-free. Secondary schools still rely predominantly on transmission pedagogies. So it may not be surprising that science teachers fear indoctrination when values should be taught in their lessons. However, all teaching is value-laden and the so-called hidden curriculum is very effective in transfer of values and adaptive socialization. The latter is contrary to the intention of public engagement and participation in the development of science and technology. Enhancing critical democratic citizenship requires the clarification of and communication about personal and societal values at stake.

Facilitator roles
In democratic pedagogies different teacher roles can be discerned.[52] The *participant* is free to express ideas, opinions and feelings just like any other member of the group. However, this could be confusing for students, because teachers have an additional professional responsibility. The *committed* teacher propagates his/her own viewpoint on a controversial issue which could result in indoctrination. The *observer* does not intervene. The *instructor* explains and clarifies relevant information, concepts and ideas, asks questions to assess understanding and gives positive or negative feedback after students' contributions. The *devil's advocate* stimulates participation by deliberately taking oppositional stances. The *advocate* presents all available viewpoints and then concludes by stating own position with reasons. The *impartial chair/neutral facilitator* encourages students' contributions and maintains the rules, but does not express personal viewpoint or give positive or negative feedback after students' contributions. *Declared interest* begins with declaring own viewpoint so that students can judge teacher's bias later.
In (empowering for) public engagement activities the role of the facilitator is crucial. Clarifying and communicating values put high demands on the facilitator in terms of creating an open, inviting and safe atmosphere, being impartial, applying questioning techniques and capturing outcomes of reasoning. Values that have been imposed in the past (adaptive socialization) can be clarified, openly communicated and critically reflected on, and finally consciously accepted or rejected.
It will be clear that it is crucial to gear the teacher's role to the stages in learning to form an opinion or make a decision. Values formation takes place through transmission, clarification and/or communication. Humans are not born but rather made through adaptive socialization, i.e. transfer or imposition of values. Or their life experiences solidify as values. Both processes are rather unconscious. Values clarification is meant to uncover and communicate these values, which subsequently enables critical reflection and further development of values. Depending on the intended values formation process certain teacher roles will be more or less appropriate. A matrix can be constructed in which the rows represent the teacher's roles and the columns the three types of values formation. How would you tick the cells of the matrix: √√, √, or – (Fig. 2)? This may be a good thinking exercise to digest what has been described above. Irrespective of the chosen role, when the occasion arises the teacher should be able to communicate and justify his own position without disqualifying other perspectives. This requires a pluralistic mind set.

[52] Harwood, D. (2010) The teacher's role in democratic pedagogies in UK primary and secondary schools: a review of ideas and research, *Research Papers in Education, 16(3)*, 293-319.

Facilitator roles	*Transmission*	*Clarification*	*Communication*
Committed	√√		
Impartial observer		√	√√
Devil's advocate		√	√√
Advocate	√		√
Impartial chair		√√	√√
Declared interest		√	√

Fig. 2. Facilitator roles in dealing with the values component of socio-scientific issues. Depending on the nature of value formation aimed at (transmission, clarification or communication) the various roles are more (√√) or less (√) or not appropriate.

To keep in mind: *doing democracy in terms of discussion and deliberation of controversial issues in classroom is crucial to prepare citizens for public engagement and participation in the development of science and technology. After this 'Why?' comes the complex 'How?'. Synthetic biology does not seem an accessible topic and teachers need scaffolding and training for addressing the values component of related socio-scientific issues. The small but steady stream of publications on the teaching of controversial issues is helpful in articulating the teacher roles and competencies and the (quality of) process and content of classroom discourses.*

Framing and meaning making

The creation of meaning to interpret and communicate perceived phenomena and events is a fundamental trait of humans. However, different people create different meanings. Framing is the process by which a person or communication source, such as a news organization, defines and constructs an issue or public controversy.[53] Holding a certain mind set or perspective is helpful in reducing the complexity of an issue and suggesting preferable solutions. Framing can be conscious or unconscious. For instance, politicians use framing as persuasion method in negotiations. The use of metaphors or analogies is also a kind of framing.

To understand why people in public debates give different meanings to applications and implications of emerging science and technology a collaborative clarification and reflection process is needed to uncover underlying assumptions, beliefs and values. Such a dialogical inquiry can be started from associations, intuitions and emotions related to (narratives, theatrical imaginations or video clips of) concrete cases or future scenarios. Coherent sets or constellations of values, beliefs and assumptions can then be identified or constructed and labelled as frames (or social representations). This will be helpful in creating mutual understanding. Dialogical inquiry might also result in reframing issues and thus contribute to bridging controversies or even consensus building.[54] The other way round is using frames that consistently appear across public debates[55] to determine the framing of past and present

[53] Kaufman, S., Elliott, M. & Shmueli (2013) Frames, framing and reframing. http://www.beyondintractability.org/essay/framing

[54] Benammar, K. (2012) *Reframing. The art of thinking differently*. Amsterdam: Boom.

[55] Nisbet, M.C., The Ethics of Framing Science. In Nerlich, B., Elliott, R. & Larson, B. (eds.) (2009) *Communicating Biological Sciences. Ethical and Metaphorical Dimensions*. Farnham: Ashgate, 51-73.

debates.[56] [57] Examples of frames are conflict, progress or gadget dominant in public debates on biotechnology, nanotechnology and information technology respectively. *Frame reflection* as practised by Athena Institute, another Dutch partner in SYNENERGENE, will be demonstrated during the WP2 workshop in Brussels.[58] Frame reflection enhances deep learning with a sustained and substantial impact on thinking, feeling and acting.

To keep in mind: *framing of issues is an on-going process at personal and societal level that should be made explicit to enable mutual understanding and bridging controversies. For educators and communicators facilitating public engagement and participation it is crucial to clarify their own frames and to be aware of how these might influence participants. Knowledge of frames that consistently appear across public debates will be helpful in positioning oneself and in articulating and overcoming deadlocks. Reframing will be promoted by dialogical inquiry, which requires mastery of questioning techniques by facilitators and participants.*

Emotional deliberation

Emerging technologies are subject to both unreasonable expectations (hopes and hypes) and irrational fear. Until now mostly scientists and experts discuss the potentials and impacts of SynBio, and not much is heard from society itself, but this could be the calm before the storm. The heated debate between the opponents and proponents of GMO remember us of fixed positions hampering a fruitful societal dialogue. Emotions reveal what matters most to us and can be indicators of which values are at stake in emerging technologies. Digging deeper into emotions through articulating[59] and interrogating them can provide justified moral beliefs and inform decision-making. When the emotions are taken seriously, people will not only feel known and understood, but they will also be more open to new information and each other's views.
Public debates about technologies are at risk of two pitfalls: the technocratic and the populist pitfall, i.e., ignore public emotions and do what the public wants[60] [61]. The former entails a focus on quantifiable hard impacts (health, safety and environmental threats) with no room for emotions and moral concerns. In the latter the emotions of the public are seen as inevitable and taken for granted without further discussion, as without public support a risky technology cannot be implemented. These pitfalls can be avoided by transcending the dichotomy between reason and emotion. By taking emotions as a source of moral reflection and deliberation they show us what beliefs concerning values are at stake and what the soft impacts (or techno-moral change[62], e.g., harming democracy, justice, privacy, dignity or interpersonal relationships) could be. Intuitions[63] and emotions are spontaneous responses, but can also be reflective, deliberative states based on past experience. Dialogue, rather than debate or discussion, seems to be indicated so as to enable collaborative

---

[56] Torgersen, H. & Schmidt, M. (2013) Frames and comparators: How might a debate on synthetic biology evolve. *Futures*, *48*, 44-54.
[57] Boerwinkel, D. J., Swierstra, T. & Waarlo, A. J. (2014) Reframing and articulating socioscientific classroom discourses on genetic testing from an STS perspective. *Science & Education,23,* 485-507.
[58] Kupper, F. (2009) *Democratizing animal biotechnology. Inquiry and deliberation in ethics and governance.* PhDthesis. http://dare.ubvu.vu.nl/bitstream/handle/1871/13312/8850.pdf?sequence=5
[59] Although related, there is a difference between emotions and feelings. Emotions are responsive and intense, but temporary, e.g. (dis)like, joy, fear, enthusiasm, anger and disgust. Feelings are low-key, but attitudinal and sustainable, e.g., worry, love and bitterness.
[60] Roeser, S. (2010) Intuitions, emotions and gut reactions in decisions about risks: towards a different interpretation of 'neuroethics'. *Journal of Risk Research, 13(2)*, 175-190.
[61] TED lecture on http://www.youtube.com/watch?v=Js6n7iwl2Co
[62] http://www.maastrichtsts.nl/?page_id=1157
[63] Intuition is immediate knowing, without reasoned analysis.

inquiry with an openness to possibilities beyond participants' own beliefs and views. *Emotional deliberation* should be included in frame reflection to balance thinking and feeling, head and heart. High demands are put on the facilitator in terms of impartiality, questioning techniques and capturing outcomes of reasoning.

To keep in mind: *intuitions and emotions should be addressed seriously in public dialogues and classroom discourses so as to meet the need of participants to feel known and understood and to keep them open-minded. In addition, if articulated, interrogated, reflected on and justified (= emotional deliberation), they provide a valuable source of moral knowledge to take into account in opinion-forming and decision-making.*

Techno-moral imagination

Discussing (un)anticipated applications and implications of new and emerging science and technology appeals to one's imaginative powers. Narratives, theatrical imaginations or movie clips of future scenarios may be supportive in outlining various aspects and perspectives voiced by (potential) stakeholders. For use in classrooms it will be very important to be attentive to any hidden persuasion due to framing, unbalanced presentation of facts or underestimating uncertainty. Furthermore, the influence of morality on technology is well acknowledged, the phenomenon of techno-moral change, i.e. the influence of technology on morality or the so-called soft impacts, is much less considered.
The Rathenau Institute has published 17 techno-moral vignettes (SynBio Futures) on her website intended to start up and fuel public debate.[64] The vignettes are short stories, informed by recent scientific publications, in which possible future applications and moral dilemmas are being introduced. The vignettes could be introduced with questions like: What are exactly the issues raised in the vignette and what has changed in the world the vignette describes? What do you think of the issues described? Which person or argument in the story do you like most, or do you see as most controversial and why? Is this indeed a future in which you would like to live? What should be done in the situation the vignette describes and who do you see as most responsible? Is there a role for politics to play?
Issues might be biosafety, biosecurity, intellectual property, distributive justice, sustainability, naturalness, biodiversity and playing God.
The educational potential of these vignettes is currently being explored by FIsme.[65] Five techno-moral vignettes were selected using criteria like time distance (not too far ahead), close to students' daily life, controversial nature, biological content and anticipated student reactions. The selected vignettes were Reinventing the dodo, Mother's day, Frustrated Housewife. Bioluminescent streetlamps and The Make-Your-Stool-Smell-Nice pill. Next these vignettes were presented to students, using individual and focus group interviews. The vignettes were helpful in imagining future developments; they raised normative and factual questions (need to know), appealed to emotions and elicited values and different types of reasoning in discussing them. The Mother's day vignette is now being used in designing a teaching and learning strategy aimed at opinion-forming.[66] A different approach in scenario learning could be to invite students to build an alternative scenario.[67] [68] Frame

[64] http://www.rathenau.nl/themas/thema/project/synthetische-biologie/synbio-futures.html
[65] De Ruijter, C. (2013). *Techno-moral vignettes: A useful tool to introduce synthetic biology related socio-scientific issues?* Master thesis Utrecht University. http://dspace.library.uu.nl/handle/1874/278453
[66] Cf. Knippels, M.C.P.J., Severiens, S.E., & Klop, T. (2009). Education through fiction: Acquiring opinion-forming skills in the context of genomics. *International journal of science education,* 31, 2057-2083
[67] http://research.acer.edu.au/cgi/viewcontent.cgi?article=1127&context=teacher
[68] The Neville Freeman Agency (2009). *Teaching for uncertain futures. The open book scenarios. A project exploring possible futures for teaching.* Canberra: Teaching Australia. http://www.futureshouse.com/downloads/teaching.pdf

analysis of the five selected techno-moral vignettes, using typologies of frames[69] [70], revealed that the risk frame was dominant in Reinventing the dodo, Mother's day and Bioluminescent streetlamps. Frustrated Housewife is framed as public accountability and in The Make-Your-Stool-Smell-Nice pill the identity/characterization frames dominate.

To keep in mind: *scenario learning as a means to techno-scientific citizenship education encourages to be proactive in choosing a desirable future for society. The use of combinations of imaginative techno-moral vignettes (SynBio Futures) enables coverage of a broad range of issues and perspectives and furthers a balanced approach. Designing an accompanying teaching and learning strategy seems promising.*

Summary of lessons learnt

It will be difficult to bridge the **rhetoric-practice gap**, that is connected with a paradigm shift, but progress can be made by setting realistic goals and carefully monitoring the translation process from ideal to practice at different levels. The descriptors of the transmission and transformation paradigm can be helpful in creating a common language for the necessary collaboration of educational designers and practitioners.

Learning theories are helpful in articulating and structuring the various interwoven learning processes included in SSI-based education. They should be applied in SynBio-related educational design and teacher education.

Realising authentic SSI-based science learning can be done when sufficient curriculum time and space is available. The key issue is **confident and competent teachers**, who need to be empowered and facilitated. Interdisciplinary collaboration in developing educational materials and activities, and cross-curricular teaching should be considered.

Science communication practitioners and scholars have much to say to science educators for use in articulating, shaping, facilitating and assessing classroom discourses through **simulating public deliberation**. At the same time they make us aware about the complexity of several interwoven learning processes which each need enough time to teach.

Doing democracy in terms of discussion and deliberation of **controversial issues in classroom** is crucial to prepare citizens for public engagement and participation in the development of science and technology. After this 'Why?' comes the complex 'How?'. Synthetic biology does not seem an accessible topic and teachers need scaffolding and training for addressing the values component of related socio-scientific issues. The small but steady stream of publications on the teaching of controversial issues is helpful in articulating the teacher roles and competencies and the (quality of) process and content of classroom discourses.

Framing of issues is an on-going process at personal and societal level that should be made explicit to enable mutual understanding and bridging controversies. For educators and communicators facilitating public engagement and participation it is crucial to clarify their own frames and to be aware of how these might influence participants. Knowledge of frames that consistently appear

---

[69] Kaufman, S., Elliott, M. & Shmueli (2013) Frames, framing and reframing. http://www.beyondintractability.org/essay/framing

[70] Nisbet, M.C., The Ethics of Framing Science. In Nerlich, B., Elliott, R. & Larson, B. (eds.) (2009) *Communicating Biological Sciences. Ethical and Metaphorical Dimensions*. Farnham: Ashgate, p. 58.

across public debates will be helpful in positioning oneself and in articulating and overcoming deadlocks. Reframing will be promoted by dialogical inquiry, which requires mastery of questioning techniques by facilitators and participants.

Intuitions and emotions should be addressed seriously in public dialogues and classroom discourses so as to meet the need of participants to feel known and understood and to keep them open-minded. In addition, if articulated, interrogated, reflected on and justified (= emotional deliberation), they provide a valuable source of moral knowledge to take into account in opinion-forming and decision-making.

Scenario learning as a means to techno-scientific citizenship education encourages to be proactive in choosing a desirable future for society. The use of combinations of **imaginative techno-moral vignettes** (SynBio Futures) enables coverage of a broad range of issues and perspectives and furthers a balanced approach. Designing an accompanying teaching and learning strategy seems promising.

Final remarks

During the SWOT analysis and further exploration of cross-cutting unifying themes it became clear that designing and implementing SynBio-related socio-scientific learning will not be a piece of cake. The socio-scientific classroom practice lags behind the rhetoric of educational policy makers and scholars. Teachers need to be empowered and facilitated in general and related to SynBio. In addition, curriculum overload and time constraints are a real hindrance to educational change. Against this background it will, in general, not be realistic to claim more than four lessons for SynBio from outside the educational system, and to dampen high expectations and to set feasible objectives. Furthermore, these lessons should substitute regular subject matter, so it will be crucial to find out where to fit in the curriculum. All the more, since SynBio as a converging, multidisciplinary techno-science builds on various knowledge bases.

In 2007 a new integrated science and mathematics subject *Nature, Life and Technology (NLT)* was introduced in secondary education in the Netherlands.[71] NLT is an elective subject, to be assessed by a school based examination, and aims at making the natural sciences and technology more attractive and coherent. This school subject provides more space and opportunities to develop a comprehensive module and accompanying in-service education for teachers. An existing module on nanotechnology[72], which nicely balances a conceptual and normative approach (scientific, ethical and societal aspects) could serve as an example. Because NLT is an elective subject, the pursuit of 'SynBio for all' has to be given up. Another approach could be to seek cross-curricular collaboration with teachers of social studies, world view education or philosophy and focus on techno-scientific citizenship education (doing democracy: deliberation, decision-making and agency).

It is hoped that this Working Paper will be helpful in finding common ground and in fine-tuning SYNENERGENE activities in formal and informal learning environments, i.e. schools and science centres and museums. Synergy could be achieved through bringing together the best of both worlds. For example, science centres and museums could provide SynBio-related hands-on activities and sensitize to socio-scientific issues, and schools could elaborate on that and address more deeply the conceptual and normative aspects through classroom teaching and discourses. Anyhow, it seems

---

[71] http://betavak-nlt.nl/english/

[72] De Vries, M.J. (2010). *Nanotechnologie: Mag wat kan?* [Nanotechnology: Ought what can be done?]. Delft: TU Delft / Nanopodium.

crucial to engage synthetic biologists, ELSA researchers, teachers and teacher educators in designing activities.

SYNENERGENE partners should feel invited to suggest opportunities for socio-scientific learning not addressed in this Working Paper. Emphasis was on the values component and on face-to-face deliberation in classrooms, but arranging online dialogues[73] following a visit to a science centre or museum might be a possibility for Ecsite partners. The mobile DNA labs provided hands-on activities for students based on lab research techniques, which were helpful in demonstrating and demystifying DNA, fascinating students and raising questions.[74] In addition, these activities enhanced their thinking and supported them to integrate knowledge learned in preceding lessons ('minds-on activities'). It will be a real challenge to find similar hands-on & minds-on activities for SynBio, but let's hope that synthetic biologists and iGEM can suggest some with educational potential. Even then there may be time and legal constraints to use them. Animation films, lego bricks or virtual tinkering activities may provide alternatives. And the educational potential of SynBio-related metaphors beyond the dominant mechanistic ones should be further explored so as to enhance conceptual understanding.
Last but not least, this Working Paper should also be considered as an invitation to SYNENERGENE partners to answer some urgent questions before starting educational design activities.

- What's really new in SynBio? Some of Rathenau's techno-moral vignettes seem to deal with genetic modification. And what's new in terms of ELSA?

- What principles and lab research techniques of SynBio are appropriate for constructing (virtual) hands-on activities for formal and informal education?

- What *realistic* and *appealing* (future) applications of SynBio could iGEM researchers and ELSA researchers recommend as appropriate for public engagement and participation activities, e.g. in constructing techno-moral vignettes?

- What metaphors and analogies have proved to be (un)helpful in public communication of SynBio?

- How are current debates on SynBio framed and what should we learn from that in terms of do's and don'ts related to education and communication?

- To promote the development of common ground and language in our community of mutual learners, which terms should be taken up in the glossary that should become part of the educational toolkit?

[73] Radstake, M., Nelis, A., Van den Heuvel-Vromans & Dortmans, K. (2009). Mediating online DNA-Dialogues From public engagement to interventionist research. *Science, Technology & Innovation Studies, 5:1,* 37-47.
[74] Van Mil, M. H. W., Boerwinkel, D. J., Buizer-Voskamp, J. E., Speksnijder, A., & Waarlo, A. J. (2010). Genomics education in practice: Evaluation of a mobile lab design. *Biochemistry and Molecular Biology Education, 38*(4), 224-229.