

The 'Synthetic Biology Learning Platform': facilitating dialogue about the Socio-Scientific Issues Concerning synthetic biology?

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RESEARCH REPORT

**The 'Synthetic Biology Learning Platform': facilitating dialogue about Socio-Scientific Issues
Concerning synthetic biology?**

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Abstract

This study evaluates whether the 'Synthetic Biology Learning Platform' ('SBLP') is a suitable and usable tool to facilitate formal and informal educators to support dialogue with students and visitors about synthetic biology (SynBio). The 'SBLP' is a digital repository that contains materials that support such a dialogue. This study looks at three specific research questions. First, the study investigates whether the 'SBLP' is a suitable tool to meet its aim. This is investigated by evaluating the platform on collected criteria found in education and communication literature, followed by semi-structured interviews with four formal and four informal educators. Secondly, this study examines to what extent the platform is a usable tool. Again, criteria are formulated, now based on usability literature. The platform is checked for these usability criteria, after which a protocol analysis is performed by the same four formal and four informal educators as participants in the semi-structured interviews. Finally, by studying the 'SBLP' on its suitability and usability, this study tries to gain insight into important guidelines for digital learning platforms that have the same aim: to facilitate educators in supporting dialogue about an emerging field of science. Suggestions for improvement that the participants gave in the interviews and protocol analysis are inductively analysed to consider additional guidelines that are missing in the previous analysis.

This study indicates that the 'SBLP' is more suitable and usable for formal educators, compared to informal educators. However, for both kinds of educators there are still some aspects that can be improved. This includes aspects such as the structure and presentation of the platform. This study finally shows that the criteria used in this study to test the suitability and usability of the platform, seem good general guidelines for the facilitation of formal educators. On the other hand, they are less applicable to facilitate informal educators. In addition, this study offers some suggestions for the improvement of the facilitation of informal educators, for example with regard to the presentation of the content on the platform.

Key-words: Dialogue, Synthetic Biology, Socio-scientific issues, Science education, digital learning platform.

Introduction

Even though scientific research is responsible for a lot of promising innovations such as the 3D printing of organs for transplantations (Schubert, Langeveld & Donoso, 2013) and developing robotic limbs that could be controlled by the mind (Nicolescu, 2011), governments have sensed a decrease in the trust of citizens in emerging science, technology and related policy. This decrease in trust grew to such an extent that, in 2000, the House of Lords Select Committee on Science and Technology called it the “crisis of distrust in science and technology” (House of Lords Select Committee on Science and Technology, 2000 chapter 2 section 36). This crisis contains the weakened public confidence in science, and in policy based on science. It is essential to reduce the ‘crisis of distrust’ in order to responsibly integrate the potential benefits of new scientific innovations into society. To reduce this ‘crisis of distrust’, scientists and the House of Lords advocated to create openness in order to engage the public and all other stakeholders involved in the research process and policy making of the emerging field of research (House of Lords Select Committee on Science and Technology, 2000; Irwin, 2006; Irwin, 2011; Wynne, 2006).

One effective and promising way to stimulate openness and engage the public in policy making and the research process is stimulating public dialogue that is related to science (European Commission, 2002; Nowotny et al., 2001). With ‘dialogue’ this study means: “the ‘multi-way’ communication between science as an academic activity and society as the larger context of science and as its potential beneficiary” (Radstake, Heuvel-Vromans, Jeucken, Dortmans, & Nelis, 2009, p.313). In other words, dialogue ensures that scientific experts learn about the concerns of the public and the public learns about emerging fields of science in reverse. Furthermore, dialogue between scientists and citizens supports Responsible Research and Innovations (RRI). RRI is a term referring to an approach to research and innovations which takes into account the societal concerns, values, priorities and institutions (Radstake, Heuvel-Vromans, Jeucken, Dortmans & Nelis, 2009). Thus, dialogue is an important factor to incorporate when one wants to make new policies or bring new responsible innovations and technologies to the market.

Accomplishing dialogue with the public about science can be challenging, especially when the discussed area of science is relatively new (Wilsdon & Willis, 2004; David & Thompson, 2011). One reason for this is that science is evolving in order to provide solutions for complex social problems related to science that our modern society is facing. These problems are also referred to as ‘wicked problems’ by Rittel & Webber (1973). Examples of such complex problems are climate change, epidemics and resource depletion. These problems are complex, for they often deal with technical uncertainty and normative diversity (Kupper & Verhoeff, 2014). The technical uncertainty of the problems relates to the fact that science is not able to provide a straightforward solution for the problem. Normative diversity is a concept that entails the occurrence of different interests for and

ideas about solutions for a problem in society. In the domain of education these problems with technical uncertainty and normative diversity are often referred to as socio-scientific issues (SSI). Socio-scientific issues are controversial social issues with a relation to science and without a straightforward answer (Zeitler & Keefer, 2003). Thus, dialogue with the public about relatively new research areas is difficult to achieve, since there is no straightforward answer available and there are different perspectives on the solution of a complex problem.

Though it seems difficult to achieve public dialogue about relatively new research fields, it is essential to achieve such a dialogue in a (democratic) society. Research shows that dialogue has a positive impact on informed and robust opinion forming and decision making (Sadler, 2011). Robust decision making is a strategy used for informed decision or policy making under conditions of uncertainty for example, technical uncertainties that may arise in relatively new and quickly developing research areas. Informed decisions are desirable, because they are based on knowledge and on the present facts. As new research fields emerge and innovations and technologies evolve, creating new informed policy's and making new informed decisions is desirable. In addition, it is desirable that citizens themselves are capable of making informed decisions when they are confronted with new technologies and innovations in their everyday life. Thus, public dialogue is highly important in order to stimulate the formation of informed decisions, in policy making as well as in everyday live.

Today, a relatively new research area that needs informed robust decision making and in which public dialogue is a necessity, is synthetic biology (SynBio). This is an emerging scientific area of expertise that combines biology and engineering in order to design biological components, such as micro-organisms which are able to decompose plastic. Despite the promising potential of SynBio, this emerging science involves socio-scientific issues and raises ethical questions, for example: 'Is it alright to create artificial life? And if so, what boundaries should be set to creating artificial life?' These socio-scientific issues and questions require reflection of the different stakeholders in order to ensure responsible research and innovation. A promising way to support these considerations of different stakeholders is to facilitate public dialogue about SynBio.

In order to support such dialogue, the Freudenthal Institute in The Netherlands created the 'Synthetic Biology Learning Platform' ('SBLP'). The 'SBLP' is a digital learning platform that aims to facilitate formal and informal science educators, such as teachers and educators in museums, so they can support students and visitors in dialogues about SynBio. Despite the fact that the platform is based on literature and professional knowledge, no clear design guidelines were available on which to base the platform. Nor do such clear design guidelines for digital platforms aiming to facilitate educators in creating dialogue about rapidly devolving sciences in general exist in literature. In addition, it is unknown how effective the approach of this 'SBLP' is in the facilitation of educators.

Therefore, this study will be a case study, focusing on 'SBLP' as the case at hand. The study will aim to evaluate whether the 'SBLP' meets its purpose and in addition, the findings of this study will generate general guidelines for future digital learning platforms aiming to support educators who wish to facilitate dialogue about an emerging science field.

Theoretical background

Synthetic biology

Synthetic biology (SynBio) is a relatively new research area that is rapidly evolving and contains potential socio-scientific issues (SSIs). So far there is no consensus on the definition of SynBio, but the European Union defined SynBio as: "...the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms" (SCENIHR, SCCS & SCHER, 2014, p.27). Synthetic biology focuses on creating new biological systems with applications in the fields of health, sustainability, scarcity of resources, and energy security. While this new form of biology is promising and potentially a 'booming' field in biological science, it also contains risks and raises SSIs and related questions without a straightforward answer. One might think for example of the risk of misuse of SynBio techniques and products with regard to bioterrorism, and SSIs related to ethical boundaries of the creation of life. The robust answers (answers that remain valuable regardless of what the exploration of the new research field brings to the table) to and decisions on these risks and questions surrounding SynBio are needed for effective policy and Responsible Research and Innovations (RRI).

In order to promote RRI in relation to SynBio, the European Union founded the SYNENERGENE project. One objective of SYNENERGENE is to stimulate public dialogue about SSIs within the field of SynBio. In order to achieve such a goal, different societal actors (stakeholders) in society work together extensively during the whole RRI process. As part of the SYNENERGENE project, the Freudenthal Institute of Utrecht University in The Netherlands created the 'Synthetic Biology Learning Platform' ('SBLP'), an online platform with the aim to support a dialogue about SynBio. The platform is a digital repository of materials and approaches for formal and informal educational settings. These educational materials and approaches aim to support teachers and museum educators so they gain insight in what SynBio entails, and to raise awareness about the SSIs surrounding this emerging technology amongst their students and visitors. However, it is unclear to what extent an online platform is able to support public dialogue about a rapidly developing science. Therefore, research in this direction is necessary.

Target audiences for dialogue

It would be ideal to create a public dialogue with the 'public at large' (all lay people in society) using a digital learning platform. However, it would be very hard, if not impossible to create one message or one platform, that is relevant for everybody. Therefore, it is better to focus on important segments of the 'public at large' through education, either formal (teachers) or informal (museum educators). It is in this way that the 'SBLP' aims to facilitate formal and informal educators.

Formal education provides an opportunity to inform students about the new research field of SynBio. By educating students, they are prepared for their societal duties as citizens. SSIs discussed in science education will furthermore lay a foundation for informed and rational decision-making in adulthood (Sadler, 2011). Thus, supporting dialogue in schools with students is important because it will have an effect on the choices they will make later on in life.

Not everyone in society can be reached through formal education, and learning is no longer restricted to the classroom. Today's society is one in which people who want to learn, get the opportunity to learn wherever and whenever they want. This process is also referred to as 'life-long learning' (Aspin & Chapman, 2000). Life-long learning includes learning in informal educational settings, such as museums or science cafés. In addition, research shows that informal science education plays an important role in creating awareness about science in communities (Storksdieck, Robbins & Kreisman, 2007). Informal settings can create opportunities for dialogue about SynBio and by doing so, these informal settings may have a positive effect on the awareness of SynBio in the surrounding community. Thus, since creating a platform with one message for the 'public at large' is hard to achieve, the 'SBLP' is focusing on two important segments of the 'public at large' i.e. formal and informal science educators.

Formal science education

Dialogue about SSIs with students has already gained interest in formal science education (chemistry, biology, physics and information technology) because it is a good way to increase the scientific literacy of the students (Sadler, 2011). Scientific literacy is explained as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (PISA, 2014, p.7). Teachers play a crucial role in the 'scientific literacy' process of students. To increase 'scientific literacy', which is one of the main goals of science education, it is important that the role of science teachers within the classroom changes (Sadler, 2011). Namely, science teachers do not only have to transfer substantial knowledge about science, they also should provide suitable contexts in which important abstract scientific concepts are being taught. For instance, when teaching about DNA, a health context could help to connect the science content about DNA to the experiences of the students. Another change in the role of science teachers is that they should coach students, instead of directing them. For example, teachers should allow students to make up and discuss their own ideas on controversial issues instead of just teaching them about the issues that live in society (Sadler, 2011). Thus, when addressing a SSI, the role of a teacher is to be a guide for their students within a dialogue about the SSI.

In general, science teachers are unfamiliar with creating and supporting dialogue with students. Curriculum constraints or a lack of confidence experienced by science teachers are reasons

for the lack of dialogue in science classrooms (Levinson & Turner, 2001). In addition, science teachers often feel overburdened (Waarlo, 2014). A reason for this could be the high turnover rate of new topics in science. All in all, the unfamiliarity with creating and supporting dialogue, the feeling of being overburdened and the high turnover rate of new topics in science are barriers if one aims to support dialogue about science with students. Therefore, if dialogue about a rapidly developing field of science is wished for in formal education, it is important to facilitate science teachers who would like to create opportunities for such a dialogue. In order to meet the aim of facilitating dialogue, the materials on the 'SBLP' should meet certain criteria in order to facilitate the science teachers. An overview of these criteria is given in the section below.

Sadler (2011) provided a framework for the design and implementation of Socio-Scientific Issue-Based Education (SSI-Based Education) in various contexts. For the establishment of the framework Sadler used a coding strategy which was similar to the coding as described in grounded theory approach (Strauss & Corbin, 1998), namely an inductive content analysis. All the existing qualitative studies about SSI education were analysed by creating a set of codes to reduce a large volume of data into a more manageable volume, from which researchers identify patterns and gain insight. Finally, this coding resulted in a framework for SSI-Based Education. In Sadler's framework for SSI-Based Education four important variables are distinguished, i.e. the design principles for SSI-Based education, the learning experience which SSI-Based education should evoke, the classroom environment in which SSI-Based education should take place and finally the teachers' attributes that are desirable for SSI-Based education. Sadler's framework is very suitable to use as a basis to analyze the 'SBLP' because of the different perspectives (the four variables) that are present and the elaborate work Sadler took into account when creating the framework. Sadler's framework seems to offer a suitable set of criteria for the analysis of the 'SBLP'. These criteria can be used to evaluate whether the 'SBLP' is able to facilitate teachers in creating a dialogue with students. The specific criteria derived from Sadler's framework for the evaluation of the 'SBLP' can be found in table 2, part 1. Table 2 contains the research tool that is used to evaluate the 'SBLP'.

Although the framework of Sadler is based on extensive research, additional educational research has been carried out since the introduction of Sadler's framework (Waarlo, 2014; De Ruijter, Knippels & Waarlo, 2014; Van Harskamp, 2016). Advice from this recent research should be taken into account as well when addressing SSI-Based education. This advice includes for example design materials with explicit learning aims that fit the curriculum (Van Harskamp, 2016), the use of issues that are closely related to students' daily lives (De Ruijter, Knippels & Waarlo, 2014), the use of contexts that induce emotions, questions, beliefs and values (Van der Zande, 2001), and providing teachers with dialogue tools, such as different 'roles' teachers could adopt during the dialogue (Waarlo, 2014). A teacher could, for instance, play the role of 'devil's advocate' in order to elicit

response of the students as well as to stimulate them to communicate their own values. In order to evaluate whether the digital learning platform is a suitable tool for meeting its purpose, advice from recent literature is added to the criteria that were already selected from Sadler's framework (2011) (see table 2; part 2).

Informal science education

How to support a dialogue on emerging science fields that contain SSIs in informal education has not been studied much. Formal and informal education differ significantly when it comes to the context in which learning takes place, and the measure in which learning is regulated. Informal education can be defined as any form of education, with the exclusion of formal education. Formal education is generally referring to regular education (van Dam & de Bakker, 2014) and will in this study refer to what is happening in classrooms of primary and secondary education. There are no boundaries when it comes to informal education. In this respect, people can learn their whole life, anytime and anywhere. In this study however 'informal education' will refer to education in an informal organization, i.e. a science museum or a science café. The distinctive features of formal versus informal science education have been studied by Hofstein & Rosenfeld (1996) and have been described by Land-Zandstra & de Bakker (2014). Their findings can be found in table 1.

Table 1. *Difference between formal and informal educational settings. Modified from Hofstein & Rosenfeld (1996) and Land-Zandstra & de Bakker (2014)*

Formal science education	Informal science education
Compulsory	Voluntary
Structured and sequenced	Unstructured and not sequenced
Assessed	Non assessed
Close ended	Open ended
Teacher-led	Learner-led
Teacher-centred	Learner-centred
Classroom context	Out of school context
Curriculum based	Non curriculum based
Few unintended outcomes	Many unintended outcomes
Empirically measured outcomes	Less directly measurable outcomes
The social intercourse is less central	Social intercourse central
Teacher and government directed	Non directed or learner directed

Although table 1 shows great differences between formal and informal educational settings that should not be overlooked, these differences are not as severe as one might think. Both educational domains promote learning, and both formulate explicit learning goals and learning trajectories. In addition, one could wonder if these differences are still important when it comes to facilitating the formal as well as informal educational professionals. In this study Sadler's framework, which originally focuses on formal education, will be used as a list of criteria to facilitate informal educators so they can support dialogue about SynBio in informal education. However, a few adaptations with respect to the context (museums instead of schools) and adjustments from recent literature will be included.

Informal educators often base their products (i.e.: 'exhibitions or lesson modules') on communication theories (Land-Zandstra & de Bakker, 2014). Thus, literature based on communication studies should be consulted in order to complement Sadler's framework (2011). Lasswell's communication model is considered to be one of the most influential within communication studies (Shoemaker, Tankard & Lasorsa, 2004). The model (figure 1) provides questions that are useful to describe an act of communication.

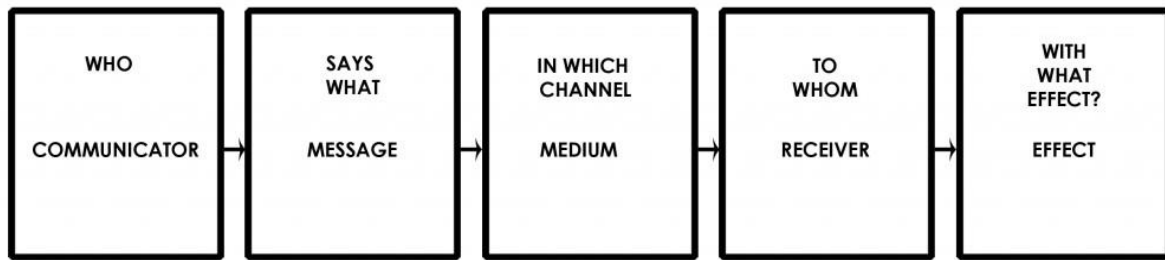


Figure 1. *Lasswell's communication model (based on Lasswell, 1949)*

The questions together can be comprised into one question: “Who Says What in Which Channel to Whom and with what Effect?” (Lasswell, 1948, p.216). These questions are very important for informal educators to be answered on the ‘SBLP’, because these also form the basis of the informal educational materials they create. Therefore, the criteria from Sadler’s framework should be completed by criteria that stem from Lasswell’s communication questions.

Recent science communication research on how to facilitate informal educators is still in an explorative state. In the last decade a study on dialogue in informal online fora took place (Radstake, Heuvel-Vromans, Jeucken, Dortmans & Nelis, 2009). They examined two different dialogues on two different topics on online platforms i.e. one about the total time of storing blood collected in standard neonatal screening (pre-born babies) and the other about genetic testing for autism. The dialogue participants were (expectant) mothers, members of non-governmental organizations (known to be against human genetics research), science experts and finally the dialogue facilitators (in this case the facilitators were working for the Centre for Society and Genomics (CSG)). The study concluded that engaging the science experts took as much effort as engaging the public (Radstake, Heuvel-Vromans, Jeucken, Dortmans, & Nelis, 2009). In the study, researchers experienced that experts were not likely to participate in the dialogue (out of five interested experts, in the end only one actually participated). The initial motivation of the expert who participated, was to merely inform the parents and make sure there were no misconceptions. However, the expert was challenged with questions by lay people that were far removed from his or her own research field. Furthermore, the expert was asked to be critical and to have an open attitude towards his/her own research field. Thus, an expert therefore has a quite difficult position in such heated discussions. As a criterion for the ‘SBLP’ the importance of the engagement of experts will be added to Sadler’s framework. These extra criteria derived from science communication literature will be used in this study to evaluate the ‘SBLP’ as a suitable tool to facilitate professionals in informal education to support visitors for dialogue about SynBio (table 2, part 3).

Table 2. *Research tool with criteria to evaluate a digital platform that aims to facilitate formal and informal educators for dialogue about a rapidly developing field of science with related SSIs. These criteria are mainly based on the framework of Sadler (2011) for SSI-Based Education with the addition of criteria drawn from further relevant and recent studies.*

Part one: criteria for a dialogue about SSI's adapted from Sadler (2011).

1. Design elements that stimulate dialogue about SSI

Containing: instructions that are built around a compelling issue, the presentation of the issue first, scaffolding for higher-order practices (e.g. argumentation, reasoning and decision-making) and ensuring a culminating experience.

2. Learning experiences that stimulate dialogue about SSI

Containing: engagement in reasoning, argumentation, decision-making and/or position taking. The confrontation with the ethical dimensions of the issue, collection and/or analysis of scientific data and reviewing the social dimensions of the issue.

3. Learning environment

Containing: high expectations for participants' participation, collaboration and interaction, a respectful and safe environment.

4. Dialogue facilitator's attributes

Containing that the facilitator should be: familiar with content and social considerations around issues, honest about knowledge limitations, willing to deal with uncertainties in the classroom and willing to position oneself as a knowledge contributor rather than sole authority.

Part two: Criteria for dialogue about SynBio in formal education drawn from recent educational literature sources.

5. Explicit learning aims that fit the curriculum.

6. SSI needs to be presented in a context related to the participants' daily life.

7. The context in which the SSI is presented needs to evoke emotions, questions, beliefs and values from the participants.

8. Providing facilitating roles an educator can adopt.

9. Providing different questions techniques.

Part three: criteria for dialogue about SSI's in informal educational settings drawn from science communication literature sources

10. Answering the question Who Says What to Whom in Which Channel with what Effect.
 11. Provide support for science experts to communicate openly about the content of their research as well as about the social and ethical dimensions around their research field.
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Digital learning platform

One way to facilitate dialogue with students and museum visitors about rapidly developing science fields is to ensure that the science educators have open access to materials and guidelines that promote and support dialogue. Online platforms could fulfil such a purpose. There is a notable increase in Information and Communication Technology (ICT) tools for education (Cook & Light, 2006). In 2012 the European Union advised to use such ICT tools to create a 'Virtual Learning Campus' in order to facilitate teachers to teach and create dialogue about the new, rapidly developing field of nanotechnology (Neicu, Millar, Schuurbiens & Bonazzi, 2012). However, a clear evaluation (of how well such a platform is able to meet its aim) seems absent in literature. In addition, other studies that evaluate platforms that aim to facilitate dialogue about new scientific research areas cannot be found in literature. Thus, more research is needed on the potential of an online platform to support dialogue on rapidly emerging science.

Usability

In order for the 'SBLP' to be a suitable for formal and informal educators, educators need to be able to easily use the 'SBLP'. Therefore, it is important that this study looks at the usability of the 'SBLP'. Other educational websites, like student learning environments or commercial websites have been evaluated on how usable they are, using several approaches, like protocol analysis (Benbunan-Fich, 2001) or comparative analysis (Bauer & Scharl, 1999). These studies focus on the usability of the digital platforms using different usability criteria. In addition, there are different definitions of usability described in literature. In this study the following definition of usability will be used: "Usability refers to how quickly people can learn to use something, how efficient they are while using it, how memorable it is, how error-prone it is, and how much users like using it" (Nielsen & Loranger, 2006, p. xvi). Basically, a usable website is one that 'communicates' clearly to the user without misunderstandings.

In order for the 'SBLP' to facilitate educators to create dialogue about SynBio, the platform should be usable with regard to a smooth navigation and an easy accessible content. To evaluate the 'SBLP' in terms of its usability, the usability criteria of Nielsen and Loranger (2006) are applied (Table 3). For practical reasons it was decided that in this study all usability criteria derived from Nielsen and Loranger (2006) are divided into 3 subgroups: one concerning the content on the website, one concerning the structure of the website and one concerning the presentation or lay out of the website. An example for a content criterion is that one page should not contain too much information. An example of a structure criterion is that important subjects that are strongly related to each other should be placed closely together. An example of a presentation criterion is that links on the website should always be highlighted using a blue colour and be underlined. Usability is about the communication between a user and the website. So in theory for a website to be usable, it should meet the usability criteria derived from Nielsen and Loranger. In addition, it should also be tested whether users experience a website as 'usable'. Therefore it is important to measure the experienced ease of use (or the 'experienced usability') by the users of the 'SBLP' (Venkatesh & Davis, 1996).

Table 3. *Tool to evaluate the usability of a website containing usability criteria (derived from Nielsen & Loranger (2006))*

<u>Content</u>
1. Home page announces the sender, aim and what the website is about.
2. The content connects well with knowledge and interest of the user (teachers / informal educators)
3. Jargon should be avoided
4. Not too much text on a page
5. Keep it simple and to the point (make the site 'robust'): only use flash, splash sound and movement if it has an additional value
6. Search engine should put most important / relevant findings on top
7. Do not only inform, also give analysis and insight
8. Make use of the inverted pyramid: start with most important information (immediately visible)
<u>Structure</u>
9. Consistent form and position of the navigation bar (commonly on the left side)
10. Search option consistent in form and position
11. Page elements that belong together should be put next to each other

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12. Do not put too much clutter on the webpages: less is more
 13. Avoid scrolling
 14. Back or undo buttons are crucial – put a home button on every page
 15. If possible, do not put too much information on one page, but click through new information in your site with the use of Hyperlinks.
 16. Links and headings should give a clear indication of the information that follows.
 17. Minimize the number of clicks
 18. Structure the page by using bullets, keywords and visual cues

Presentation

19. Avoid pop ups or content which is framed as an advertisement
 20. Use drop down menus but keep them small and use them sparingly
 21. Keep site uniform / conventional
 22. Links are always blue and underlined, have a proper name and change colour once used
 23. Keep the amount of moving elements to a minimum
 24. Make search a button
 25. The number of font styles and colours is limited and used consistently
 26. Use high contrast, preferable dark letters on cool, desaturated background colours
 27. When using audio make sure the information can also be read in the text somewhere
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The Synthetic Biology Learning Platform

The 'SBLP' is a digital learning platform that aims to facilitate formal and informal science educators, such as teachers and educators in museums, so they can support students and visitors in dialogues about SynBio. The platform contains six yellow buttons, visible in figure 2, which guide the users to the following materials. 'Home' leads to the home page. 'Classroom activities' (activiteiten voor in de klas), contains lesson modules and other teaching materials. 'Activities for informal settings' (Buitenschoolse activiteiten) contains non-school-based materials and events about SynBio. 'Auxiliary materials' (hulpmiddelen) contains sources about guidelines, manuals and tips for dialogue. 'Subject information' (Informatie over het onderwerp) offers sources with both basic and more in-depth information about synthetic biology. And finally 'socio-ethical aspects' (Socio-ethische aspecten) contains sources about the potential impact of synthetic biology on society.

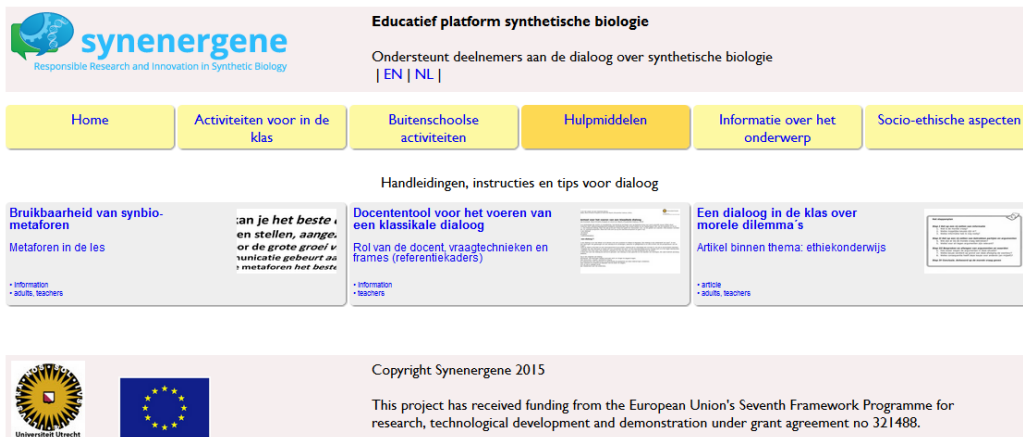


Figure 2. Screenshot of the Synthetic Biology Learning Platform- subgroup Auxiliary materials. This subgroup shows that there are three different materials presented on the platform that will provide helping materials which the users can use to conduct a dialogue about SynBio with their target audience.

Behind each of the six yellow buttons, several materials or source options can be explored by the user (figure 2). When the platform user makes a specific choice for one of the materials by clicking on one of the blue headlines, a short summary appears and the link to the material will be presented (figure 3).



Figure 3: Screenshot of the Synthetic Biology Learning Platform after choosing a specific material or source. In this case the screenshot shows a short summary of the guidelines for good metaphors in order to communicate the developments in SynBio, presented under the button 'auxiliary materials'.

As can be seen in figure 2, the platform allows the user to choose for either a Dutch platform or an English platform. The Dutch part of the platform there are a total of 24 different materials and sources, while the English platform has a total of 25 materials and sources. Some of the materials

and sources that are presented on both the Dutch and the English platform are similar, then the language is the only difference between them. Other materials and sources on both platforms are completely similar because some of the materials on the Dutch platform will guide the user to materials in English for instance, an English short video. However other materials are specific for either the English platform or the Dutch platform. For practical reasons this study focuses only on the materials that are present on the Dutch part of the platform.

Research questions

The purpose of this case study is to evaluate if the 'SBLP' is a suitable tool to facilitate formal and informal educators to support dialogue with students and visitors about SynBio. Two research questions emerge from the theoretical framework and need to be answered in order to evaluate whether the digital learning platform meets its aim. First it is important to evaluate if the platform is a suitable platform. Secondly, it is important to study the conditions under which the 'SBLP' is properly functioning. Additionally, by studying the 'SBLP' as a case, this study tries to find guidelines for digital learning platforms with a purpose of facilitating educators in supporting dialogue about an emerging field of science. This leads to a third research question that will focus on the general guidelines. The three research questions are formulated as follows:

1. Is the 'Synthetic Biology Learning Platform' a suitable tool to facilitate professionals in formal and informal education to support students and visitors for dialogue about synthetic biology, and if so, to what extent?
2. Is the 'Synthetic Biology Learning Platform' a usable tool for formal and informal educators, and if so, to what extent?
3. What guidelines for a suitable and usable digital learning platform which will facilitate formal and informal educators so they can support a dialogue with their audiences about a rapidly evolving science field can be derived from this particular case study?

Method

In order to explore whether the 'Synthetic Biology Learning Platform' (SBLP) is able to facilitate formal and informal educators so they can support dialogue about SynBio with their audiences, this study will look at the suitability and usability of the 'SBLP'. By studying the particularly 'SBLP' as a case study, this study hopes to derive guidelines for future digital learning platforms with the same purpose. Below a short overview of the method which is used to answer the specific research questions can be found, followed by a more elaborate description.

Overview method

The first research question about the suitability of the learning platform, will be investigated in two ways. First, the suitability of the 'SBLP' will be analysed by using the research tool with criteria that are used to determine the suitability of the platform in terms of facilitating educators to support a dialogue about SynBio, described in the theoretical framework (table 2). Secondly, semi structured interviews with formal and informal educators will be performed.

The second research question, to find out whether and to what extent the platform is a usable tool to support dialogue about science, will also be investigated in two ways. First, the 'SBLP' will be analysed using the usability criteria explained in the theoretical framework (table 3) generated from Nielsen & Loranger (2006). Secondly, a protocol analysis (Benbunan-Fich, 2001) will be performed in order to determine the 'experienced usability' of the platform by the users.

To answer the third and final research question (what guidelines for a suitable and usable digital learning platform can be derived from this particular case study) the transcripts of the answers of the semi-structured interviews and the protocol analysis will be read and re-read, in order to look for additional critical remarks. These critical remarks will be inductively analysed in order to formulate (additional) guidelines for a digital platform. Figures 4 shows a visual overview of the research methods used in this study.

Question 1 (suitable)	Question 2 (usable)	Question 3 (guidelines)
<ul style="list-style-type: none">• suitability platform analysis• Semi-structured interviews	<ul style="list-style-type: none">• usability platform analysis• protocol analysis	<ul style="list-style-type: none">• semi-structured interviews / protocol analysis

Figure 4 Overview of research questions and used methods in this study.

Participants for protocol analysis & semi-structured interviews

In the protocol analysis and the semi-structured interviews, four formal educators and four informal educators participated. All participants were Dutch for only the Dutch part of the platform was evaluated. All of the educators volunteered to cooperate with the study and no objections were given for their participation. Among the formal educators, all of them biology teachers, there were two males and two females. Their experience varied from being a novice teacher (almost one year's experience) to a soon-to-be retired teacher (38 years' experience). Their ages differed from 24 to 63. Among the informal educators there were one male and three females. Their experience differed from 3 to 15 years' and their ages differed from 28 to 48 years old. Two of the informal educators worked at a museum, i.e.: 'Museum' and 'Universiteitsmuseum Utrecht'. Their jobs mainly concerned exhibit development. One of the informal educators worked as a project manager at 'Wetenschapsknooppunt Utrecht'. His job consists of connecting schools (primary and secondary education) to scientists. For instance, he arranges that scientists visit schools and makes sure there is dialogue between the children/students and the scientist. The fourth participant is a science programmer for a television program where scientists share their knowledge about the science they studied with the public. The television program is called 'De Universiteit van Nederland'. Her job consists of finding and interviewing scientists with an interesting and accessible story about their own science field and scientific expertise. All of the participants, formal and informal, were experienced users of the world wide web and none of them used or saw the 'SBLP' prior to taking part in this study. The protocol analysis and semi-structured interviews took place over a four-week period in the months May and June of 2016, at their work places.

Platform analysis

The 'SBLP' is analysed by the author in terms of its suitability and usability by comparing the platform with the criteria present in the theoretical framework (an overview of 'suitability criteria' can be found in table 2, and of 'usability criteria' in table 3). When a page of the 'SBLP' met one of the criteria, this page was noted behind this specific criterion. For example, one criterion presented in table 2 is that when one wants to create dialogue about SynBio, it is important to build the instruction around a compelling issue. If in the 'SBLP' compelling issues were presented, the page on which these issues can be seen was noted. An overview of this analysis can be found in appendix 2. Since the analysis was undertaken by the author of this thesis, it was repeated by a university staff member for more reliability of the results the analysis generated. The results were checked and compared regarding similar and different points of view. There were only two points on which the author and the staff member disagreed. However, after they discussed the results of the analysis they both came to an agreement.

Protocol analysis

A protocol analysis is a research method that induces verbal reactions from participants. There are different ways to evaluate the usability of websites, but a protocol analysis has been found to be the most effective method to emphasize specific usability problems (Henderson, Smith, Podd & Varela-Alvarez, 1995). In addition, it tests the 'experienced usability', or in other words the usability that the target audience experiences. Protocol analyses in usability studies work with a 'talk-out-loud' protocol. In this protocol participants are given a specific task on the website and are asked to verbally express all their actions and task-specific thoughts (Benbunan-Fich, 2001).

In the study on the 'SBLP', eight individual sessions with participants were studied, and all these sessions started off with a protocol analysis as described above. Beforehand the participants were told very little about what the study would be about. The researcher used a script to introduce the task to the participant to make sure each session started off similarly (see appendix 1). The specific task the participants were asked to do on the 'SBLP', entailed that the platform and its contents needed to be used by the participant, in order to prepare an activity or a lesson that would involve a dialogue with their audiences about SynBio. Each session was audio-taped and the researcher noted any notable events. Beforehand an agreement was made between the researcher and the participant about how the researcher should remind the participant to 'think-out-loud' if necessary. The maximum time for the educators to spend on the platform preparing a dialogue was 20 minutes. However, in all cases less time was spent on the platform since all educators rapidly indicated to have 'a good impression of the platform'.

Semi-structured interviews

After the protocol analysis participants were asked 12 questions in a semi-structured interview about how they experienced the suitability of the platform. The topic-list for the semi-structured interviews can be found in appendix 1. The topic-list was developed on the basis of the criteria in table 2. The topic-list was created with the input from several peers and a university lecturer. The interview was pre-tested with a fellow master student before the actual interviews in the study were held. Topic order was flexible, in order to leave room to discuss interesting items with the participant. This way the advantages of semi-structured interviews were fully used (Denscombe, 2003).

Questions on the topic-list are related to the criteria for a dialogue about SynBio (table 2) as previously discussed in the theoretical framework. For instance, when a criterion for dialogue was: 'to build the instruction around a compelling issue', the question was formulated as follows: 'does the 'SBLP' facilitate you in finding compelling issues about SynBio for your audience?'. Each question contained a follow-up question which asked if the participant found this criterion important in terms

of feeling facilitated in supporting a dialogue about SynBio. So in the example at hand, the participant was asked if compelling issues are important for a dialogue about SynBio. Due to time limitations, not all the criteria were present in the interviews. The specific criteria for formal and informal education (table 2: part two and three) were not taken into account because of practical reasons, i.e. the interviews would take far too much time. In addition, some criteria were more or less merged together into one question. For instance, the criteria under 'learning environment' were combined into one single question: 'To maintain a good effective dialogue it is important to maintain several conditions, like a safe and respectful environment, stimulation of an environment with high expectations of participants, encouragement of collaboration and interaction among students. Did you find supporting materials on the platform that you could use to create such a suitable environment for dialogue?' The interviews lasted about 40 minutes on average. All interviews were audio-taped and transcribed for later data analysis.

Data analysis

All protocol studies and semi-structured interviews were transcribed leaving out vocalized pauses and sounds like 'um', 'mm-hm', and 'eeh' (Denscombe, 2003).

For the protocol analysis, two phases within the data analysis followed, i.e. the scanning and the scoring phase. In the scanning phase the verbal transcript was read and reread and scanned in order to identify moments of interest or 'critical comments' (instances of a misunderstanding, problem or difficulty in the interaction of the educator with the platform). These critical comments were scanned and structured within the three usability parameters, i.e. content, structure/navigation and presentation. In the scoring phase the frequency in which critical comments occurred, was calculated for the three parameters separately. Also the distinction between formal and informal educators was made when the frequency was calculated. This result is presented in a bar graph (figures 5). A quarter of all critical comments in the transcript was coded by another researcher and the Inter-rater reliability (Cohens Kappa) was substantial (Landis & Koch, 1977) namely, $\kappa = 0,78$. This indicates the reliability of the data for the protocol analysis is substantial.

The qualitative data of the semi-structured interviews was structured by the 12 different questions on the topic-list, which in turn was related to the suitability criteria for dialogue about SynBio (table 2). The reactions of the participants were deductively analysed by labelling the answers as either a positive or negative reaction to the questions. A quarter of all the answers the participants gave was also labelled by another researcher and the inter-rater reliability (Cohens Kappa) was almost perfect (Landis & Koch, 1977) namely, $\kappa = 0,91$ – indicating a good reliability of the data from the interviews. Thus, the analysis provided a possible indication of the 'experienced suitability' of the 'SBLP' by the participant.

Finally, an inductive approach was used to develop guidelines for a digital platform that aims to facilitate educators to support a dialogue about an emerging science field. This inductive analysis included both the transcripts of the protocol analysis and the transcripts of the semi-structured interviews. All transcripts were read several times in order to identify moments when a participant gave suggestions for improvement. Any comment which a participant indicated as important for the digital learning platform was labelled as a suggestion for improvement. For instance, a suggestion could be: 'I would emphasize the aim of the platform more on the homepage, explain the aim and why it is important to address such an aim'. The collected suggestions were read repeatedly to consider possible meanings of the suggestions. Then suggestions were categorized. For instance, the previously mentioned example would be a suggestion that would be labelled under a 'clear aim' category. This structured the data and gave insight in the additional criteria that the participants found important for a digital platform. A quarter of all 'suggestions' or 'critical comments' in the transcript was coded by another researcher to raise the reliability of the data and the inter-rater reliability was good (Landis & Koch, 1977) namely, $\kappa = 0,82$. This analysis provided a possible indication for additional guidelines that can be derived from this particular study on the 'SBLP'. These guidelines might be useful for future platforms facilitating educators to support dialogue about rapidly developing sciences.

Results

Question 1: Is, and if so, to what extent, the ‘Synthetic Biology Learning Platform’ a suitable tool to facilitate professionals in formal and informal education to support students and visitors for dialogue about synthetic biology? To answer this first research question about the suitability of the learning platform, information was gained from two sources. First, the suitability of the ‘SBLP’ was analysed by the author using the criteria explained in the theoretical framework (table 2). Secondly, semi-structured interviews with formal and informal educators were performed. The results will be discussed below.

Suitability analysis

An overview of the results of the suitability analysis is visible in table 4. Criteria that are present on are indicated with a ✓ sign. If a criterion is absent, this is indicated with a – sign. Some criteria are present on the platform, even though they are hard to find or only implicitly mentioned. These criteria are indicated with a / sign. For example: the criterion about paying respect to each other is not explicitly present on the platform. However, the teacher tool does mention what a teacher could do if students do not (want to) understand each other’s view. The advice given will stimulate paying respect to each other even though the criterion ‘paying respect to each other’ is not *explicitly* mentioned on the platform, and thus the criterion is marked with a / sign. All the results of the criteria analysis will be discussed below table 4.

Table 4. *Results of criteria for suitability analysis*

Part one: criteria for a dialogue about SSI’s adapted from Sadler (2011).	
Design Elements	
1 Build instruction around a compelling issue	✓
2 Present the issue first	-
3 Provide scaffolding for higher-order practices (e.g. argumentation, reasoning and decision-making)	✓
4 Provide a culminating experience	✓
Learning Experiences	
5 Reasoning, argumentation, decision-making and/or position taking is promoted	✓
6 The ethical dimensions of the issue are considered	✓
7 Scientific data related to the issue are considered	/
8 The social dimensions of the issue being considered	✓

Classroom Environment	
9 High expectation for participant's participation	√
10 Collaborative and interactive	√
11 Participant and dialogue facilitator demonstrate respect for one another	/
12 Participant and dialogue facilitator feel safe within the environment	-
Dialogue facilitator's attributes	
13 Familiar with issues being considered (science content & social considerations)	√
14 Honest about knowledge limitations	√
15 Willing to deal with uncertainties in the classroom	-
16 Willing to position oneself as a knowledge contributor rather than sole authority	√
Part two: Criteria for dialogue about SynBio in formal education drawn from recent educational literature sources.	
17 Explicit learning aims that fit the curriculum	√
18 SSI needs to be presented in a context related to the learners' daily life	√
19 The context in which the SSI is presented needs to evoke emotions, questions, beliefs and values from the participants	√
20 Providing facilitating roles an educator can adopt	√
21 Providing different questions techniques	√
Part three: criteria for dialogue about SSI's in informal educational settings drawn from science communication literature sources	
22 Answering the questions Who Says What to Whom in Which Channel with what Effect.	-
23 Provide support for science experts to communicate openly about the content of their research as well as about the social and ethical dimensions around their research field	/

Overall, out of the twenty-three criteria, sixteen criteria were clearly present on the platform. Four criteria were missing on the platform i.e. criterion 2 'present the issue first'; criterion 12 'participant and dialogue facilitator feel safe within the environment' and criterion 15 'willing to

deal with uncertainties in the classroom'. Also, criterion 22 'answering the questions Who Says What to Whom in Which Channel with what Effect' is only partly present on the platform. One can easily find the aim and sender on the homepage of the platform even though they are not further explained. The target audiences become clear in the headings on the homepage, but these are also not explicitly explained or discussed anywhere on the platform. Other than that, the choice for the medium of a digital repository is not explained on the platform, and neither has the intended effect. Nowhere can be found why dialogue about SynBio is the intended effect.

Three criteria were implicitly present on the platform. Firstly, criterion 7 'scientific data related to the issue are considered' was considered implicitly present. The scientific data are not actually presented on the platform. On the platform there are however articles that translate the scientific data and there are a lot of references to scientific data. Secondly, criterion 11 'participant and dialogue facilitator demonstrate respect for one another' is implicitly present. This criterion comes somewhat forward in the teacher tool on the platform, where tips and tricks are provided for guiding a dialogue. It is the authors' opinion that these tips and tricks can contribute to a respectful environment. And finally, criterion 23 'provide support for science experts to communicate openly about the content of their research as well as about the social and ethical dimensions around their research field' was found implicitly present on the platform. It is the authors' opinion that the materials provided on the platform can contribute to more openness of scientists about SynBio, although it is not specifically addressed on the platform. It should also be noted that most criteria are present in the lesson module¹ and teacher guide² on the platform. These materials altogether make sure that all the specific criteria in part 3 of table 2 for the formal educators are met by the platform, as well as almost all criteria in part 1 of table 2.

The specific criteria for informal educators are not present in the teacher guide nor in the lesson module. Nonetheless, the teacher tool in the teacher guide provides information and it is the author's opinion that these could be useful for informal educators as well. Surely, these materials are in need of some sort of a 'translation'. Now they are written for teachers, and specifically address them as such. For instance, the materials could have less text and more visualisations and the activities in the lesson module could be divided into different shorter activities. This way parts of the

¹ This lesson module guides students through the forming of an opinion on issues concerning SynBio. The lesson module contains 5 components. First students will gather information on what SynBio contains. Secondly, students will pick one application of SynBio from a few preselected applications. In the third part students will inform themselves in groups on a chosen application. Fourthly students will form an opinion in groups on how desirable this application of SynBio is for society. Finally, the groups will present their outcome and a dialogue with all participants is held. The lesson module contains a guide for the teacher as well as material for students.

² The teacher guide for the implementation of a classroom dialogue provides teachers with the information i.e. why a dialogue is important, the role of the teacher during the dialogue, questioning techniques and different reference frameworks from which arguments of SynBio can be interpreted.

lesson module could become more suitable for informal educators. So, it is important that these materials are translated to a broader audience, including informal educators for instance.

Semi-structured interviews

After the platform analysis, semi-structured interviews were held to see whether educators would find the platform suitable, in terms of facilitating them in supporting a dialogue with their audience of choice. The basis for the questions in these interviews were the same criteria (stemming from table 2) as the ones that were used in the platform analysis. Participants were asked whether they could detect the criteria on the platform.

All the teachers, four in total, felt facilitated by the platform. However, only one of the four informal educators felt facilitated by the platform. The other three informal educators felt that the platform did not offer them materials to support a dialogue about SynBio. The aim of the platform was not clearly present on the platform. Only one formal and one informal educator felt they had a good and clear idea of the aim of the platform and formulated the aim of the platform as being about creating a dialogue about SynBio. All participants (both formal and informal educators) felt that creating a dialogue about science was part of their job and none of the participants felt insecure about creating such a dialogue and about supporting their target audiences during the dialogue.

All in all, the teachers gave more positive reactions on the questions in the semi-structured interview compared to the informal educators: 27 positive reactions were given by teachers, and 19 by informal educators. This means that teachers could find more of the suitability criteria of table 2 on the platform. Informal educators could trace back less criteria on the platform and therefore they felt possibly less well facilitated. Moreover, only one informal educator said she felt facilitated by the platform (compared to four out of four teachers). She states: 'yes, now that I've seen the instructional instruments on the platform I would be facilitated. I mean I expect that it would be valuable for me. Nevertheless, I have not seen everything'. Taking the above into consideration this means that the platform seems more suitable for formal educators compared to informal educators.

Question 2: Is, and if so, to what extent, the 'Synthetic Biology Learning Platform' a usable tool for formal and informal educators? To answer the second research question, two sources are consulted. First the 'SBLP' is analysed by the author using the usability criteria explained in the theoretical framework (table 3) generated from Nielsen & Loranger (2006). Secondly, a protocol analysis (Benbunan-Fich, 2001) is performed in order to determine the 'experienced usability' of the platform as experienced by the users.

Usability analysis

An overview of the results of this analysis can be found in table 5. Criteria that are present on the platform are indicated with a ✓ sign. If a criterion is absent, this is indicated with a – sign. Some criteria are inconsistently present on the platform. These criteria have been given a / sign.

Table 5. *Results of the usability analysis*

Usability criteria	
Content	
1. Home page announces the sender, aim and what the website is about.	✓
2. The content connects well with knowledge and interest of the user (teachers/ informal educators)	✓
3. Jargon should be avoided	-
4. Not too much text on a page	/
5. Keep it simple and to the point (make the site robust): only use flash, splash sound and movement if it has an additional value	✓
6. Search engine should put most important / relative findings on top	-
7. Do not only inform, also give analysis and insight	✓
8. Make use of the inverted pyramid: start with most important information (immediately visible)	✓
Structure	
9. Consistent form and position of the navigation bar (commonly on the left side)	✓
10. Search option consistent in form and position	-
11. Page elements that belong together should be put next to each other	✓
12. Do not put too much clutter on the webpages: less is more	✓
13. Avoid scrolling	✓
14. Back or undo buttons are crucial – put a home button on every page	✓
15. If possible do not give new information in a new window but click through new information in your site	✓
16. Links and headings should give a clear direction	-
17. Minimize the number of clicks	-
18. Structure the page by using bullets, keywords and visual cues	✓
Presentation	
19. Avoid pop ups or content which is framed as an advertisement	✓
20. Use drop down menus but keep them small and use them sparingly	-
21. Keep site uniform / conventional	✓

22. Links are always blue and underlined, have a proper name and change colour once used	-
23. Keep the amount of moving elements to a minimum	√
24. Make search a button	-
25. Number of font styles and colours is limited and used consistently	√
26. Use high contrast, preferable dark letters on cool, desaturated background colours	√
27. When using audio make sure the information can also be read in the text somewhere	-

Table five shows that most usability criteria that are related to “content” of the platform are met, namely five out of eight. The same goes for most usability criteria related to “structure” (seven out of ten), but only five out of nine usability criteria related to “presentation” are met.

With regard to the “content criteria”, sometimes jargon is used, which can be a problem (criterion 3). In some of the descriptions of the materials on the platform jargon is used: e.g. techno moral vignette & custom oligonucleotide synthesis’ below subject information. These terms are not likely to be terms that fall under the day-to-day language of lay people. In addition, the criterion that there should not be too much text on one page (criterion 4) is almost met. On the platform itself, there is not too much text presented on one page. However, the materials to which the platform links or materials that the platform offers, sometimes consist of a lot of text. Therefore, the platform itself meets this criterion but the sources it offers sometimes don’t. The final content criterion that is not met by the platform is that there is no search option available on the platform, and therefore this option does not put the most important / relative findings on top (criterion 6). On the other hand, it could be argued that a search option is not so relevant for this platform because it is a very small platform that contains only 24 Dutch materials.

When it comes to the “structure criteria”, this search option is not in a consistent form and position (criterion 10), which is irrelevant because there is no search option, and one can argue if there should be one with the small amount of materials present on the platform. Another structure criterion that is not met by the platform is that the links and headings should give a clear direction (criterion 16). Some headings on the platform are very clear, for instance the buttons with ‘Subject Information’ or ‘Classroom activities’. Nonetheless, if one visits one of these headings, one will arrive on a page with less obvious guiding headings. For instance, if one clicks on ‘Subject information’, different materials appear, like ‘what is synthetic biology’, ‘synthetic biology’, and again a heading with ‘what is synthetic biology’. First off, it does not become immediately clear what the interrelation between these headings is, and what the materials behind these headings are. In addition, some headings are a bit misleading, like the heading that says ‘now really synthetic, how to make a new

cell?'. This heading suggests that after clicking it, you can learn the activity of making a new cell. However, behind this heading is a quite a long article with all kinds of information, also on the history of synthetic biology. It is not until page 17 that one finds information on how to build a new cell. When one uses the platform this information would be expected to become directly available. Finally, the number of clicks (criterion 17) are not minimized on the platform. When clicking on 'subject information' on the home page, you will enter a page with different headings. When selecting a heading, you will enter a different page with more information about what the material behind this heading entails. Finally, there you can click to a link with the specific information. By using such a website structure, the number of clicks is not reduced.

In terms of the "presentation criteria", the platform does not use 'drop down menus' (criteria 20) which is recommended if one uses them sparingly and keeps them small. The links to the materials on the platform are not blue and underlined, do not have a proper name nor do they change colour once used (criterion 22). Also, search is not a button (criterion 24). Finally, the audio of the movies that are included in the materials cannot be read in text anywhere else (criterion 27).

Protocol analysis

After the platform usability analysis, a protocol analysis followed to test the 'experienced usability' of the platform by formal and informal educators. Critical moments were selected and divided into the three categories, in line with the division of the usability criteria: content, structure and presentation. Critical moments were moments where the participant was expressing a misunderstanding, problem or difficulty in the interaction with the platform. An overview of the results is presented in figure 5.

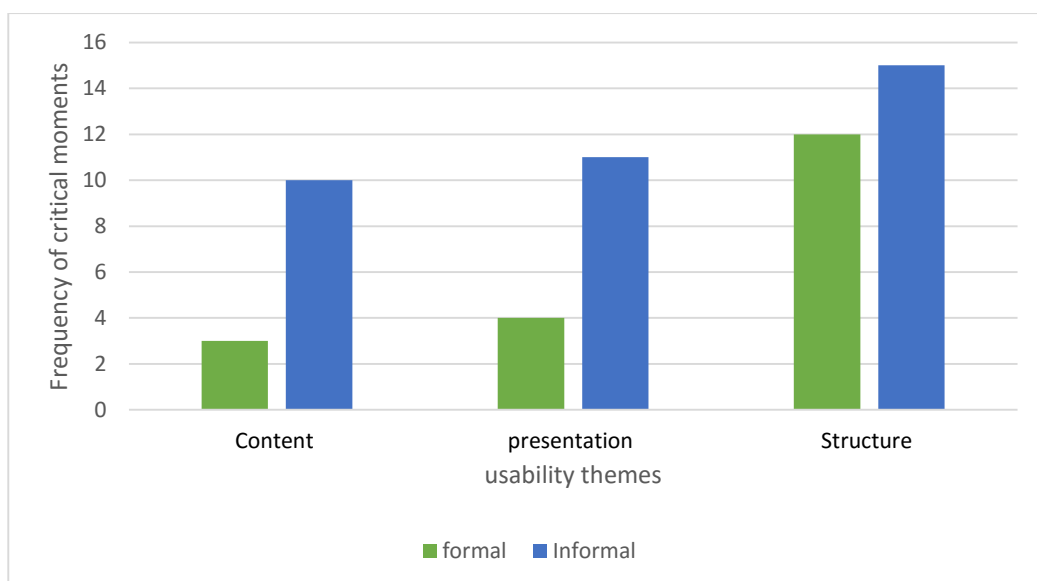


Figure 5. Critical moments experienced by formal and informal educators related to either "content", "structure" or "presentation" of the platform.

Figure 5 shows that most critical moments occurred with regard to the structure of the platform. Participants indicated that they found repeats on the platform, had navigation problems, had different expectations of the order on the platform, had trouble figuring out where to click or did not find the platform properly organized. An organization problem for instance was, that participants struggled to discover the interrelations between the materials on the platform.

With respect to “presentation” participants did not find the design and layout of the platform very appealing. They were often driven away to another platform, like ‘*Kennislink*’ during the protocol analysis. Even though they were told that their task was to explore the ‘SBLP’. Some participants found that there was too much use of the English language on the Dutch platform. And finally, participants felt that the presentation of the information on the platform was unclear. The mutual relationship between the materials on the platform under one of the six yellow buttons was not clear on the platform. The least critical moments concerned the content of the platform. The critical moments that appeared in this area were about different expectations of the content of the materials on the platform and the sender of the platform, the goal of the platform and the target audience.

Question 3: What (additional) guidelines for a suitable and usable digital learning platform which will facilitate formal and informal educators so they can support a dialogue with their audiences about rapidly evolving science can be derived from this particular study? To answer the third and final research question, the author went through the transcripts of the semi-structured interviews and the protocol analysis, in order to gain insight in what (additional) guidelines for a digital platform are important. Moreover, the author searched for moments in these transcripts where the participants gave additional suggestions in order to complement the research tools (about the suitability and usability) used in this study, things the participant themselves indicated as important.

(Additional) guidelines

First the responses to the criteria in the research tool that is used in this study to check for the suitability (table 2) is discussed. Formal educators felt that all criteria that were present in the semi-structured interviews were of value for a platform that aims to support a dialogue about SynBio. For informal educators, the criteria about the learning environment (safe and respectful environment prompting high expectations of participants, collaboration and interaction between participants) and characteristics of the professional (competent feeling to engage in dialogue) were

of less value. Especially the criteria about the social and ethical dimensions were highly valued by formal as well as by informal educators.

Furthermore, this study collected suggestions for improvement given by the participants during the protocol analysis and the semi-structured interviews. These were suggestions for improvement that cannot be related to the two research tools that were used in this study, i.e. the suitability criteria and the usability criteria. These suggestions were inductively analysed so that the categories emerged from the data. The result of these emerged categories is presented in table 6. Per category, the number of times they occurred is given, followed by the number of teachers and informal educators who addressed this category.

Table 6. *Additional suggestion for improvement: counts and sources.*

<u>Category for improvement</u>	<u>N</u>	<u>Teachers</u>	<u>Informal educators</u>
1: Provide an attractive platform.	16	3	4
2: Provide a clear and simple dialogue tool with an overview of different perspectives of the dialogue. It should be clear at one glance.	10	3	3
3: Give concrete cases, (provocative) statements or examples of SynBio in (future) everyday life, preferably on the homepage.	9	1	4
4: Make sure that there is interaction/dialogue between the platform and platform visitors.	8	1	3
5: Include a visualization of the scientists behind the research field.	7	1	3
6: Name the latest developments, and make sure these are up to date.	5	2	2

Table 6 shows an overview of the results of the inductive analysis with the most mentioned advisory comments on top, gradually counting down to the least mentioned suggestions at the bottom. All participants gave several suggestions for improvement with the exception of one teacher, who had just started teaching. She had no suggestions for the ‘SBLP’ whatsoever and was very satisfied with it. She mostly appreciated the lesson module and the teacher tool, which she found both very useful. The different categories will be described in more detail below.

Category 1. Provide an attractive platform.

A lot of suggestions were given concerning the presentation of the platform. For example: ‘The platform is very pale. There is no emotion visible on the platform, and it is a very emotional topic. It

is not dynamic at all. You do not see what kind of different learning resources are present on the platform. It should be made more attractive'. More images, mind maps and/or schedules are suggested. As an example of an attractively looking platform 'Kennislink' was mentioned multiple times, by teachers as well as by informal educators. One teacher noticed that the presentation of the platform was simple and solid. He said he could imagine why the people designing the platform had chosen for a simple and solid looking platform instead of an attractively looking platform. However, he still would suggest a more attractive design for the platform and even suggested that maybe someone should be hired to make the platform more attractive.

Category 2. Provide a clear and simple dialogue tool with an overview of different perspectives of the dialogue.

Teachers valued the concrete guidance on how to support a dialogue with students about SynBio in the teacher tool. Another point the participants made was that they would like to have a clear overview of the dialogue itself. Who is pro SynBio, who is against it? Which positions exist? This information should become clear at a glance, preferably in a scheme or schedule, and not in a long article.

Category 3. Give concrete and clear cases, (provocative) statements or examples of SynBio in (future) everyday life.

The content of the concrete cases on the platform under the 'techno moral vignette'³ was highly appreciated by all participants. Most participants would have liked to see more of the concrete cases on the platform. Some participants suggested that the platform should start with these concrete cases. For example, a participant stated: 'It is of course an exciting field of science in the end. Although this is not immediately clear when you enter the platform. It becomes clear in the case about the luminous trees and the cases under the 'techno moral vignettes' which are fine, concrete cases. However, you should start your platform with these concrete cases'. Other participants also acknowledged the importance of the concrete examples: 'Because this (refers to the concrete case) gives SynBio a kind of concreteness, and that is a huge help when one wants to introduce SynBio'. Although both participants express their excitement about the concrete cases, they were both less appreciative of where they could find the cases on the platform. Thus, concrete cases seem to be a big help when addressing quickly developing but complicated science fields, and are of most help when one wants to introduce SynBio. One of the participants suggested putting changing images on the homepage with (provocative) statements for instance, a picture of an illuminating tree, with the statement 'Illuminating trees should replace streetlamps'.

³ This source of the platform contains five stories about future scenarios for synthetic biology. The stories describe potential SynBio applications and the impact they could have on society. These stories could be used as a starter of a dialogue.

Category 4. Make sure that interaction/dialogue is possible between the platform and platform visitors.

The platform is quite static at this point. There is no possibility to interact with each other on the platform. As one participant puts it: 'This does not feel like a platform because the sender is SYNERGENE. If something is a platform I would expect to see Henk, a teacher from a secondary school, on the platform saying that he used this for... which was great fun. So to me something feels like a platform when all sorts of people are already doing things on it and I can interact to see a Twitter feed or to see that there is at least some activity'. All in all, four participants mentioned that interaction with the platform and their users is important when the platform wants to meet its aim. Yet, the participants referred to different interactions, like exchanging materials, a poll that visualises the opinion of the platform visitors about SynBio or the possibility of exchanging experiences and tips and tricks on dialogue about SynBio.

Category 5. Include a visualization of the scientists behind the research field.

Especially informal educators would like to have seen the faces of scientists behind SynBio. Some even wanted to see the faces of the people behind the platform and how the teachers and informal educators make use of the platform: 'I feel a distance that makes it less meaningful for me. Yes, well maybe it might be too much like contemporary marketing communications. I do not see the people behind the platform or the scientists behind SynBio'.

Category 6. Name the latest developments, and make sure the platform is up to date.

The participants found it important that the platform is up to date. This point is similar to the interaction point. The participants want to know what is happening at this point in time, which will make the platform livelier. 'A platform for me is something where things are shared continuously. Have you been to the last conference already? If not, you can read about it here. Or recent articles have come up, you will find them here. Just something that lives; the 'SBLP' does not feel like a platform now.'

Other suggestions for improvement of the 'SBLP'.

Finally, three suggestions that were given do not fit into any of the categories. Nevertheless, they are still worthwhile to mention. To start with, the target audience of the platform are formal educators and informal educators. Some participants still had trouble to determine the target audience of the specific materials on the platform. Two informal educators had problems figuring out who the target audience was for the platform itself. In addition, they could not figure out who the target audience was for the materials on the platform. The target audience of the materials is mentioned on the platform, but in very small lettering. In addition, the target audience is not very much specified. 'I would like much more specific information about target groups. This is not really a

choice model'. For instance, the target audience for the lesson module is secondary school students (adults). That does not make clear if it is for VMBO, HAVO or VWO. And for which grade is it suitable?

One teacher stated: 'On the platform, having a dialogue is a teaching method that is tied to one specific topic, namely SynBio. My first reaction is that it is a big platform for such a 'small subject'. I would like to see a platform for dialogue in biology for instance and that you can apply the materials of that platform in different biological contexts. There is simply more to talk about in biology than only synthetic biology. There are also very many other new interesting developments in biology like bionics for instance'.

A final suggestion given by one of the teachers, is to make the aim and the why of the aim very explicit on the platform: 'For me it is still not very clear why we should talk about SynBio? Is it because they are afraid that there is as much discussion and fear about it as with the introduction of biotechnology? I do not sense that the fear is there though. But I do not know the concept very well. Or is the aim of the platform purely to bring SynBio to the attention and that the users of the educational platform apply this knowledge onto their audiences?' The participant clearly gets confused about the aim of the platform. It could be suggested that the aim, and the importance of the aim should be explained more elaborately on the platform.

Conclusion

This study evaluated whether the 'SBLP' meets its purpose, and by doing so to generate guidelines for future digital learning platforms that support educators to facilitate dialogue about an emerging science field. Three research questions were raised to investigate this aim.

The first question was studied by a platform analysis and by semi-structured interviews. The question was: Is, and if so, to what extent, the 'SBLP' a suitable tool to facilitate professionals in formal and informal education to support students and visitors for dialogue about synthetic biology? In this study, the platform analysis indicated that the 'SBLP' has the potential to facilitate formal educators in a better way compared to informal educators. However, the platform analysis indicates a few important aspects which should be considered in order to facilitate both groups of educators: i.e.: for formal and informal educators. The issue about SynBio should be presented first on the platform (criterion 3), there should be advice included on how to ensure a safe environment for the dialogue and finally, the uncertainties that the fast developing field of SynBio brings and how educators can cope with these uncertainties when supporting dialogue should be addressed on the platform. In the platform analysis the specific criteria for formal educators (table 2 part 2) are all met, while the specific criteria for informal educators (table 2 part 3) are not fully met. This indicates that the platform is more suitable for formal educators than for informal educators. The semi-structured interviews also indicate that the 'SBLP' has more potential to be suitable to facilitate formal educators rather than the informal educators. The formal educators expressed that there were more criteria present on the platform compared to informal educators. This was nicely illustrated by the answers to the question "do you feel facilitated by the platform". On this question three out of four formal educators answered with: 'yes' while only one out of four informal educators answered the same question with: 'yes'. This difference between formal and informal educators reveals itself in the other questions of the semi-structured interviews as well.

The second question asked if and if so, to what extent, the 'Synthetic Biology Learning Platform' is a usable tool for formal and informal educators. This question was studied through a platform usability analysis and a protocol analysis. The outcome of the platform analysis in terms of usability indicates that the usability of the website was considered quite good, although there is room for improvement, especially considering the presentation of the platform. For example, it is important to underline links on the platform and give them a blue colour. Furthermore, the protocol analysis indicates that the 'experienced usability' by educators is not very good, especially not for informal educators. Informal educators experienced more critical moments compared to formal educators on all three usability categories i.e. content, structure and presentation. The usability category that needs the most attention is the structure of the platform. For instance, it is important

that it is clear how the materials on the platform are interconnected or related to each other. The user can then more easily distinguish between the materials on the platform.

The final question was: what are guidelines for a suitable and usable digital learning platform which will facilitate formal and informal educators so they can support a dialogue with their audiences about a rapidly evolving science? This question was answered by studying the semi-structured interviews and the protocol analysis, and by doing an inductive analysis of the suggestions for improvement that were given by the participants. This study indicates that the criteria described in the theoretical framework for a suitable platform that aims to facilitate dialogue about quickly developing sciences (table 2), are good guidelines for formal education. All formal participants suggested that they indeed needed these aspects to feel facilitated. For informal education the criteria about the learning environment (safe and respectful environment prompting high expectations of participants, collaboration and interaction between participants) and characteristics of the professional (feeling competent to engage in dialogue) were of less value. In addition, the participants had suggestions for improvement. They mentioned the importance to provide an attractive platform, a clear and simple dialogue tool with an overview of different perspectives of the dialogue, concrete cases, (provocative) statements or examples of SynBio in (future) everyday life, preferably on the home pages, interaction/dialogue between the platform and platform visitors, visualization of the scientists behind the research field, a clear organisation of the platform, the latest developments, (and make sure these are up to date).

Taking everything in consideration, the author's advice for the platform would be to focus on only one target audience for the platform: i.e. formal educators. In addition, if one still wants to contribute to the facilitation of informal educators, it would be an idea to look at exciting platforms that have been mentioned several times in the interviews, for instance '*Kennislink*'. Moreover, the author would advise to have a close look at the presentation of the materials on the platform and make them more appealing. Ensure more 'spark' on the platform: a more attractive appearance and more images for instance. In addition, the platform could also ensure more 'spark' by highlighting more of the provocative statements on the platform. Finally, the structure of the platform can use a clear build up, then it would be easier to guide through, and distinguish between the different materials presented on the platform.

Discussion

This study investigated the suitability and usability of the 'SBLP' and tried to generate guidelines for a digital learning platform that aims to facilitate educators that want to support a dialogue about SynBio. The reader should bear in mind that this was an explorative research study and that the criteria and additional guidelines emphasised in the conclusion of this study apply for the 'SBLP' and one should be very careful to generalize these findings onto other digital platforms. All participants firstly evaluated the 'SBLP' during the protocol analysis. The questions in the semi-structured interviews that followed were in context of the 'SBLP' i.e. 'do the stories on the platform match the everyday world of the students?'. Although, after that first question a more general question followed i.e. 'is it important that stories on the platform relate to the everyday world of your target audience in order to be suitable to facilitate you?' Even so, because the participants had already seen the 'SBLP' they might not have been as objective. Rather than generalizing the outcome of this study, this study can be seen as a 'proof of principle' i.e. the study shows that it seems that a tool such as the 'SBLP' can indeed meet its aim, though partly, and facilitates formal educators to support a dialogue on SynBio with their students. Nevertheless, it is interesting to further investigate whether the criteria and additional guidelines also apply to other platforms.

Another potential problem considering the generalisation of the results of this study is the small group of participants. In this study only four formal and four informal educators participated. That means that the study cannot say by all means something general that counts for all formal or all informal educators. Thus, it is important to keep that in mind when acting on the advice that is given in this study. In addition, another potential obstacle in this study could be that the definition of informal education used in this study is too broad: i.e. all education outside formal education. It is hard to figure out how to facilitate informal educators when there are so many different jobs for informal educators. Although informal education is known for its broad view on educational settings, a more specific definition of informal education (or a more specific definition of an informal educator) maybe could have given more insight in the 'needs' of (specific) informal educators and how they are facilitated for a dialogue about SynBio. Moreover, the sample of informal educators used in this study might not have been ideally chosen. The jobs of the different informal educators are widespread leading to widespread needs for a platform. When a more specific group of informal educators was chosen, perhaps a more in-depth view of the needs of those specific informal educators could have come up.

Furthermore, this study indicates that the 'SBLP' is more suitable and usable to facilitate formal educators than the informal educators. This might not be surprising, considering that there are schools to prepare for a job as a formal educator. To become a teacher, you need to have a teacher degree. On the other hand, there are no schools to prepare for a job as an informal educator.

This illustrates the fact that there is a body of knowledge around on how to facilitate formal educators, while little is known on how to facilitate informal educators. For instance, formal educators are familiar with the use of a lesson module; it is a clear structure which always contains the lesson goals, the time the lessons will take etc. Such a lesson module is also present on the platform and so teachers will feel facilitated by the platform because they can find a lesson module, something they are familiar with. Informal educators on the other hand lack such a clear communication structure. In order to facilitate informal educators, it is important to gain insight in good suitable communication structures which facilitates informal educators.

It is important to bear in mind that the the research tool on suitability (table 2) was mainly based on literature from the realm of educational studies. The platform analysis and semi-structured interviews are mostly based on the framework of Sadler (2011) for SSI-Based education. In addition, the background of the author, as well as the background of the platform designers is in formal education. For example, in the semi-structured interviews, the specific criteria for formal and informal education (table 2: part two and three) are not taken into account because of practical reasons, i.e. the interviews would take far too much time. Thus, the semi-structured interviews that are preformed are mostly based on criteria derived from formal education. This could unexpectedly have influenced the research in a way that formal educators were more likely to give a positive response to the interview questions compared to informal educators because of the language that was used during the interviews. In order to avoid this next time interview questions should be consulted with an informal communication expert in order to make sure the language is similar to what informal educators are familiar with.

Another potential problem is that the use of usability criteria in this study may be too elaborate. The 'SBLP' is only a small platform. In the usability evaluation criteria such as 'Search engine should put most important / relative findings on top', and 'Search option consistent in form and position' and 'Make search a button' are less important for a small platform like the 'SBLP'. Next time a selection of important criteria should be made in order to prevent this problem.

It is beyond the scope of this study to examine the effect of the 'SBLP' on the dialogue that takes place in the classroom or in an informal setting. For instance, it could be a very suitable and usable tool for educators however when the tool has no positive impact on real dialogue that takes place than one might consider other tools which could have this positive impact. In an ideal situation you would like to measure the impact that the platform has on the dialogue that takes place in order to measure how well the platform facilitates teachers and informal educators. Digital learning platforms are not the only way to facilitate formal and informal educators. You could conduct a teacher training, or meetings where formal and informal educators share their ideas around dialogue in the classroom, visiting science cafes around the dialogue topic, or consulting real science experts

about the topic. It could be very interesting to investigate in a follow up study, how well the platform facilitates educators compared to the use of other approaches like a teacher training.

As part of answering the third research question i.e. 'what guidelines for a suitable and usable digital learning platform can be derived from this particular case study', the author looked at additional remarks the participants gave. These remarks however, go far behind the intention of the platform, because the platform aims to be a 'digital repository'. It seems that the participants want the platform to be more than merely a digital repository. They want to be up-to date regarding the latest developments, have interaction and be part of the dialogue before supporting such a dialogue with their target audiences. This advice seems to go much further than the digital repository initially was intended to go. These 'guidelines' therefore might seem a little farfetched and time and money consuming to achieve. Moreover, the additional guidelines that arose from the data in this study are only based on eight participants. It therefore is a little premature to call them additional guidelines for a digital platform. Nevertheless, it is the authors opinion that in order to optimize the dialogue these 'guidelines' could be taken into account.

References

- Aspin, D. N., & Chapman, J. D. (2000). Lifelong learning: concepts and conceptions. *International Journal of Lifelong Education*, 19(1), p. 2-19.
- Benbunan-Fich, R. (2001). Using protocol analysis to evaluate the usability of a commercial web site. *Information & management*, 39(2), 151-163.
- Cook, J., & Light, A. (2006). New patterns of power and participation? Designing ICT for Informal and Community Learning. *E-Learning and Digital Media*, 3(1), 51-61.
- Coombs, P., & Ahmed, M. (1974) *Attacking Rural Poverty: How Nonformal Education Can Help*. Baltimore: Johns Hopkins University Press
- Corrigan, D., Dillon, J. & Gunstone, R. (Eds.) (2007). *The Re-Emergence of Values in Science Education*. Rotterdam / Taipei: Sense Publishers.
- Dam, van, F., Bakker, de, L., & Dijkstra, A. M. (2014). *Wetenschapscommunicatie, een kennisbasis*. Den Haag: Boom Lemma.
- David, K., & Thompson, P. B. (Eds.). (2011). *What can nanotechnology learn from biotechnology?: social and ethical lessons for nanoscience from the debate over agrifood biotechnology and GMOs*. Academic Press.
- European Commission (2002) *Science and Society Action Plan*. Brussels, Belgium: European Commission
- Davies, S., McCallie, E., Simonsson, E., Lehr, J. L., & Duensing, S. (2009). Discussing dialogue: Perspectives on the value of science dialogue events that do not inform policy. *Public Understanding of Science*, 18(3), 338-353.
- Harwood, D. (2001). 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.
- Irwin, A. (2006). The politics of talk coming to terms with the 'new' scientific governance. *Social studies of science*, 36(2), p. 299-320.
- Irwin, A. (2014). Risk, science and public communication. *Routledge Handbook of Public Communication of Science and Technology*, 160.
- Kolb, S. M. (2012). Grounded theory and the constant comparative method: valid research strategies for educators 3(1), 83-86.
- Land-Zandstra, A., Bakker, de, L. (2014). Informele wetenschapseducatie. In F. van. Dam, L. de. Bakker, & A.M. Dijkstra (Ed.), *Wetenschapscommunicatie, een kennisbasis*. (p. 85-110) Den Haag: Boom Lemma.
- Landis JR, Koch GG. (1977). The measurement of observer agreement for categorical data. *Biometrics*; 33(1), 159–174.

- Lasswell, H. D. (1948). The structure and function of communication in society. *The communication of ideas*, 37, 215-228.
- Lasswell, H. D. (1949). Why be quantitative? *Language of Politics: Studies in Quantitative Semantics*, The MIT Press, Cambridge, MA, 40-52.
- Levinson, R., Turner, S., Koulouris, P., Desli, D., Douglas, A., Evans, J., & Kirton, A. (2001). The teaching of social and ethical issues in the school curriculum arising from developments in biomedical research: a research study for teachers.
- Kupper, F., Verhoeff, R. (2014). Wetenschap in dialoog. In F. van. Dam, L. de. Bakker, & A.M. Dijkstra (Ed.), *Wetenschapscommunicatie, een kennisbasis*. (p. 85-110) Den Haag: Boom Lemma.
- Neicu, M., Millar, J., Schuurbijs, D., Bonazzi, M. (2012) *Reaching Out to the Future. Outline of Proposals for Communication Outreach, Dialogue and Education on Nanotechnology*. Luxembourg: Publications Office of the European Union
- Nicolelis, M. (2011). *Beyond Boundaries: The New Neuroscience of Connecting Brains with Machines--and How It Will Change Our Lives*. Macmillan.
- Nielsen, J., & Loranger, H. (2006). *Prioritizing web usability*. Pearson Education. Nowotny H, Scott P, Gibbons M (2001) *Re-thinking Science. Knowledge and the Public in an Age of Uncertainty*. London, UK: Polity Press
- PISA 2015 Science Framework (PDF) (Report). OECD. March 2013. Retrieved 15 October 2014.
- Radstake, M., van den Heuvel-Vromans, E., Jeucken, N., Dortmans, K., & Nelis, A. (2009). Societal dialogue needs more than public engagement. *EMBO reports*, 10(4), 313-317.
- Rittel, H. W. (1972). *On the Planning Crisis: Systems Analysis of the " First and Second Generations"* p. 390-396. Institute of Urban and Regional Development.
- Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, 4(2), 155-169.
- 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, p. 355-369.
- SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks), SCCS (Scientific Committee on Consumer Safety), & SCHER (Scientific Committee on Health and Environmental Risks), Synthetic Biology I Definition, Opinion, 25 September, 2014.
- Shoemaker, Pamela; Tankard, Jr., J. and Lasorsa, D. (2004). *How to Build Social Science Theories*. Thousand Oaks: Sage Publications. p. 109

- Schubert, C., van Langeveld, M. C., & Donoso, L. A. (2013). Innovations in 3D printing: a 3D overview from optics to organs. *British Journal of Ophthalmology*, *bjophthalmol*- 2013.
- Select Committee on Science and Society, House of Lords, Session 1999-2000, 3rd report, Science and Society (London: HMSO, HL Paper 38, February 2000).
- Storksdieck, M., Robbins, D., & Kreisman, S. (2007). Results from the quality field trip study: Assessing the LEAD program in Cleveland, Ohio. *Cleveland, OH: Summit Proceedings*.
- The Directorate-General for Research and Innovation of the European Commission (2012). "research and innovation - Europe's ability to respond to societal challenges" (PDF). <http://ec.europa.eu/research/science-society>. Retrieved 9 June 2014
- Venkatesh, V., Davis, F., (1996) A model of the antecedents of perceived ease of use: development and test, *Decision Science*, *27* (3) p. 451-481
- Waarlo, A.J. (2014). Enhancing Socio-Scientific Issues-based Learning in Schools, D2.1 SYNENERGENE, co-funded by the European Commission under the 7th Framework Programme, Karlsruhe, Germany / Utrecht University, Freudenthal Institute for science and mathematics education (NL).
- Wynne, B. (2006). Public engagement as a means of restoring public trust in science—hitting the notes, but missing the music?. *Public Health Genomics*, *9*(3), p. 211-220.
- Wilsdon, J., & Willis, R. (2004). *See-through science: why public engagement needs to move upstream*. Demos.
- Zeidler, D.L. & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education: Philosophical, psychological and pedagogical considerations. In D.L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education*. The Netherlands: Kluwer Academic Press. (pp. 7-38).

Appendix 1

Protocol analyse and interview script

Sessie _____

Datum _____

Onderzoeker _____

Tijd begin _____

Tijd eind _____

Gegevens deelnemer

Leeftijd: _____ geslacht: _____ Beroep _____

Werkervaring: _____

TOPIC LIST:

Introductie

Voorstellen

- Wie ben ik?
- Wat kom ik doen?
- Deelnemer bedankten voor het interview

Uitleg onderzoek

- Onderzoek naar hoe formele en informele educatie professionals optimaal gefaciliteerd kunnen worden als ze iets met synthetische biologie willen in hun werkomgeving. En specifiek hoe ze gefaciliteerd kunnen worden voor het houden van een dialoog over synthetische biologie met hun doelgroep.
- Mijn doel is om te evalueren of het 'Educatief Platform Synthetisch Biologie te evalueren' een dialoog kan faciliteren.
- Als onderdeel daarvan zou ik u graag met u naar het platform kijken.
- Het is belangrijk dat we onderscheid maken tussen discussie en dialoog. Een discussie is vaak competitief van aard en dialoog coöperatief. In een dialoog worden mensen niet gedwongen om een standpunt te verdedigen, waardoor er gelegenheid is om iets te leren van de perspectieven van de andere mensen. Bij een debat of discussie het doel om een meningsverschil op te lossen, zodanig dat er uiteindelijk een winnaar is.

Verloop van het interview

- Duur ongeveer een uur
- Ik ben vooral geïnteresseerd naar uw ervaring en mening, er zijn geen goede of foute antwoorden.

- Ik vraag u zo of ik het interview mag opnemen. Voor de analyse en de rapportage zal u naam nergens genoemd worden alleen u leeftijd, geslacht en beroep. Als u toestemming geeft vraag ik na het aanzetten van de tap recorder nogmaals of u toestemming geeft.

Protocol

- Uw rol in nu om met een doel de website te bezoeken, namelijk dat u een dialoog over synthetische biologie wilt verzorgen met uw doelgroep. Tegelijkertijd vraag ik u om uw aanpak, de stappen die u neemt en alle ander taak-specifieke gedachten hard op uit te spreken. In andere worden wordt u gevraagd om 'hard op te denken'.
- <Demonstreren van de 'hard op denkmethode' >
- Zoals gezegd zullen al uw worden opgenomen worden voor de latere analyse. Daarom is het belangrijk dat u al uw gedachten uitspreekt. Mijn taak in deze is om uw acties te noteren, uw te observeren, uw stem op te nemen en u eraan te herinneren om 'hard op na te denken', mocht u dat vergeten. Ik kan u dit eerste onderdeel niet helpen met de site of vragen beantwoorden.
- Nadat u een goede idee heeft gekregen van de inhoud van de site die voor u van belang is voor het voorbereiden van een dialoog over synthetische biologie gaan we over op het tweede deel van het interview. Daarin stel ik u nog een aantal vragen stellen over de inhoud van het platform. Om de tijd te bewaren krijgt u maximaal 20 minuten om het platform te bestuderen, daarna gaan we over op het interview.
- Heeft u nog vragen over dit protocol, over uw taak het doel van mijn onderzoek of iets anders voelt u zich dan vrij om die nu nog aan mij te stellen. Zo niet dan gaan we beginnen.

<Aanzetten taperecorder>

Toestemming opname

- Geeft u toestemming voor het opnemen van deze bijeenkomst zodat ik de gegevens anoniem kan verwerken?

Inhoud platform

1. Welk doel heeft dit platform naar uw idee?
 - Is dat doel duidelijk geworden op het platform, heeft u dit doel kunnen terugvinden op het platform?
2. Ondersteunt het platform u wanneer u een dialoog zou willen aan gaan over synthetische biologie met uw doelgroep?
 - Op welke manier wel of niet?

- Welke elementen waren hiervoor bruikbaar?
- Hoe zou u deze elementen gebruiken?
- 3. Vind u het houden van een dialoog met uw doelgroep over sociale issues die een relatie hebben met science als onderdeel van u beroep? Waarom wel/niet?

Ontwerp elementen

- 4. Wat vindt u van de verhalen over SynBio op het platform?
 - o Zijn ze overtuigend en geschikt voor uw doelgroep? Sluiten ze aan bij u doelgroep?
- Is dit belangrijk voor het houden van een dialoog?

Leerervaring

- 5. Bevat het platform handvaten om mensen te betrekken bij argumenteren, beslissingen maken en meningsvorming over synthetische biologie?
 - o Ja: Wat vindt u van deze handvaten/ Zou u ze gebruiken? Zo ja hoe?
 - o Nee: Hoe zou je hier wel mensen in kunnen ondersteunen?
- Vindt u dat een platform dit zou moeten bevatten, Is dit belangrijk voor het houden van een dialoog?

- 6. Bevat het platform materiaal over de verschillende ethische kwesties die spelen rondom SynBio?
 - o Ja: Waar en welke? Zou u deze gebruiken? Zo ja hoe?
 - o Nee: Vindt u dat het platform dit zou moeten bevatten
- Is dit belangrijk voor het houden van een dialoog, om hier vooraf iets van te weten?

- 7. Bevat het platform wetenschappelijke informatie over SynBio?
 - o Ja: Waar en welke? Zou u deze gebruiken? Hoe?
- Vindt u dat het platform dit zou moeten bevatten, Is dit belangrijk voor het houden van een dialoog?

- 8. Bevat het platform informatie over de maatschappelijk impact (sociale dementi's) van SynBio?
 - o Ja: Waar en welke? Zou u deze gebruiken? Zo ja hoe?
- Vindt u dat het platform dit zou moeten bevatten, Is dit belangrijk voor het houden van een dialoog?

Leeromgeving

9. Om een goede effectieve dialoog te houden moet aan een aantal voorwaarden worden voldaan. Het is belangrijk dat er een veilige en respectvolle omgeving wordt gecreëerd waarin hoge verwachtingen van deelnemers gevraagd wordt, en samenwerking en interactie bevordert worden. Vindt u ondersteunende materialen voor het creëren van een geschikte klassenomgeving op het platform? Welke en waar.
- Vindt u dat het platform dit zou moeten bevatten?

Karakteristieken van de professional

10. Ondersteunt dit platform u in uw gevoel van zekerheid als het gaat om het aangaan van een dialoog over synthetisch biologie?
- Waarom wel of niet? Hoe?
 - Uitonderzoek blijkt in de formele educatie komt naar voren dat docenten zich vaak niet zeker voelen (bekwaam) over hun kwaliteiten om een dialoog over wetenschap aan te gaan met hun doelgroep? Geld dit ook voor u? Waarom wel/niet
- Zou een platform hierin kunnen en moeten ondersteunen?

Is er inhoudelijk nog iets anders aan het platform opgevallen dat nog niet ter sprake is gekomen tijdens dit interview?

Appendix 2

This table contains the criteria for the SBLP. These criteria are based on the framework of Sadler (2011) and on recent formal and informal education literature. The SBLP is evaluated according to these criteria. The result is presented right side of this table. When a criterion is represented on the SBLP this is indicated with a code. This code refers to the webpages on the SBLP where the information is found that is needed in order to meet the criteria. When a criterion is absent on the SBLP this is indicated with: "-". Some webpages on the SBLP can be indirectly contribute to one of the criteria. When this is the case then this is indicated by the word indirectly in front of the webpages code.

Criteria	The codes in this column represent codes of pages of the SBLP that contain materials that fit the criteria in the same row.
Part one adapted from Sadler (2011)	
<u>1. Design elements</u>	
Build instruction around a compelling issue	28323/ 28449 /28272
Present the issue first	-
Provide scaffolding for higher-order practices (e.g. argumentation, reasoning and decision-making)	28272/ 28422
Provide a culminating experience	28272
<u>2. Learning Experiences</u>	
Reasoning, argumentation, decision-making and/or position taking is promoted	28272
The ethical dimensions of the issue are considered	28272/ 28449/ 28323/ 28328 / 28424 / 28451/ 28452 /28452 / 28329
Scientific data related to the issue are considered	28272
The social dimensions of the issue being considered	28449/ 28323 / 28424 / 28451 /28452/ 28329
<u>3. Classroom Environment</u>	
High expectation for participant's participation	28272

	Indirectly: 28422
Collaborative and interactive	28272
Participant and dialogue facilitator demonstrate respect for one another	-
Participant and dialogue facilitator feel safe within the environment	-
4. <u>Dialogue facilitator's attributes</u>	
Familiar with issues being considered	Indirectly: 28309, 28310, 28312, 28313, 28315, 28316, 28317, 28450, 28323, 28328, 28329, 8424, 28449, 28451, 28452, 28453
Honest about knowledge limitations	-
Willing to deal with uncertainties in the classroom	-
Willing to position oneself as a knowledge contributor rather than sole authority	Indirectly: 28422 / 28428
Part two: Specific elements for formal synthetic biology education drawn from recent literature sources	
<u>5.</u> Explicit learning aims that fit the curriculum	28272
<u>6.</u> SSI needs to be presented in a context related to the learners' daily life	28323/ 28449
<u>7.</u> The context in which the SSI is presented needs to evoke emotions, questions, beliefs and values form the participants	28449
<u>8.</u> Providing facilitating roles an educator can adopt	28272 / 28422
<u>9.</u> Providing different questions techniques	28272 / 28422
Part three: Specific elements for informal synthetic biology education drawn from recent literature sources	

10. Answering the questions Who Says What to Whom in Which Channel. Homepage

11. Provide support for science experts to communicate openly about the content of their research as well as about the social and ethical dimensions around their research field - in between the lines in different materials
