# Leveraging Learning Experiences in Sustainability-oriented Challenge Prizes

**Yasmin Barroso Bastos**

**Salla Kuuluvainen**

**Cecília Soares Braga**

Blekinge Institute of Technology

Karlskrona, Sweden

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## Yasmin Barroso Bastos, Salla Kuuluvainen, Cecília Soares Braga

School of Engineering
Blekinge Institute of Technology
Karlskrona, Sweden
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**Abstract:** The way our society currently operates undermines the basic conditions for life on Earth. In order to address the Sustainability Challenge there is a need for learning new ways of thinking and for alternative learning spaces, such as Challenge Prizes. They are competitions that offer rewards for anybody who can develop a solution for a defined challenge and can be seen to implicitly use a Problem-based Learning approach. This thesis investigated how sustainability-oriented Challenge Prizes could implement a more rigorous PBL approach and include learning about Strategic Sustainable Development. The research methods were qualitative interviews with three groups of experts. The results show that Challenge Prize processes currently facilitate learning through innate qualities like offering opportunities for group work and by bringing together diverse stakeholders, but there is opportunity for improvement. SSD can be included in the process when setting the specific challenge and creating the winning criteria. The PBL approach could be used as an inspiration. It was seen that Challenge Prizes can contribute towards disseminating knowledge about the SSD with the support of PBL through their learning-by-doing nature.

**Keywords**: Challenge Prize, Sustainability, Strategic Sustainable Development, Problem-based Learning, Contest, Sustainability Challenge
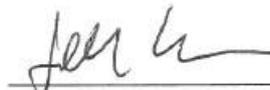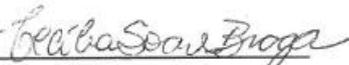
# Statement of Contribution

Since the group formation, we talked about our learning objectives and decided that we wanted to contribute equally in all the parts. It was important for us to use our previous knowledge and experiences, but also to learn many new things. We wanted this process to be harmonious and collaborative.

In this research most of the practical work was shared equally among us. All decisions regarding the overall planning of the research design, for example formulating research questions, deciding on research methods and development of research goals were taken together. Duties regarding the written report were also shared equally as well as duties related to data collection and analysis, like finding interviewees, interviewing them and transcribing interviews. Data analysis methods were as well carried out by all team members.

Individually, each one contributed with particular skills and characteristics. Cecilia brought calmness to the process as well as dedication to do all the referencing. Salla kept the passion for the topic alive and contributed with visual graphics. Yasmin brought her positive energy to every meeting and contribute to formatting the document. The group process was great and led us to finish this project with a positive note.

Yasmin Barroso Bastos          Salla Kuuluvainen          Cecília Soares Braga

# Acknowledgements

# Executive Summary

**Introduction**

The Earth has entered an era called the Anthropocene, in which the human influence on the Earth's system is greater than natural forces. The way our society currently operates is undermining basic conditions for all life on Earth. Thus, Earth is now considered to be operating in an unprecedented state, in which multiple, complex, interacting, and globally significant changes happen due to human activities at an exponential rate. Our society is operating on a model of constant growth, which is inappropriate considering the finitude of Earth's resources. Competition is a driver of this model, which is one key factor that contributes to most of the problems society currently faces.

The understanding of the dependence of human life on the environment, rather than its dominance over it, led to the definition of sustainable development. However, the attempts to define sustainable development usually results in vague concepts. In order to make informed choices and move towards sustainability, organizations need a clear framework and definition of sustainability.

A strategic and scientific approach called Strategic Sustainable Development (SSD) was developed in order to address this need. SSD is based on a systems thinking approach as it strongly recommends that a systems perspective is used when dealing with complexity and therefore with the Sustainability Challenge. Strategic Sustainable Development addresses the lack of agreement with an operational definition for sustainability by eight Sustainability Principles (SPs), which provide boundary conditions within which humanity can create a sustainable society.

The Sustainability Challenge is complex and requires reflection and social learning in order to address it effectively. Research also shows that education for sustainability requires deep learning, systems thinking and an interdisciplinary approach. The university community seems to be lacking in these aspects and therefore there is a need to seek for alternative learning approaches and spaces.

Problem-based learning (PBL) is a learning approach that has characteristics that can assist in solving the sustainability challenge since the methodology involves a transdisciplinary approach, collaboration, diversity and an iterative nature in the learning process, which are similar to the requirements for addressing the Sustainability Challenge. Due to its similarities to real life settings, PBL resembles alternative learning spaces, such as Challenge Prizes.

Challenge Prizes are contests that offer rewards for individuals or organizations that can develop a solution for a defined challenge. Challenge Prizes have a long history in helping humans to invent solutions to complex problems in different societal fields from space technology to agriculture, and they offer a way for organizations to invite diverse stakeholder groups from outside to innovate solutions to problems.

One often overlooked outcome of Challenge Prizes processes is that they can function as environments for learning. The Challenge Prize process is defined as the process of the competition, from the launch until the awarding of the prize. This process has the the potential to create a space for experimentation, fostering more effective solutions, while benefiting from a variety of ideas that come from several participants and a collaborative space. There are many

sustainability-oriented Challenge Prizes that could benefit from implementing SSD, since research states that SSD is an approach that has characteristics that are beneficial for learning about sustainability, and it would offer a definition of sustainability that would help defining the victory conditions.

**Research Purpose and Questions**

This research aims to investigate how sustainability-oriented Challenge Prizes could implement a more rigorous Problem-based Learning approach and include learning for Strategic Sustainable Development in their process.

Primary Research Question:

- In what way could sustainability-oriented Challenge Prizes, supported by Problem-based Learning, help facilitate learning for Strategic Sustainable Development?

Secondary Research Questions:

- How do Challenge Prizes facilitate learning?
- In what ways could the learning process of sustainability-oriented Challenge Prizes be improved by a rigorous application of Problem-based Learning?
- Could the learning processes of sustainability-oriented Challenge Prizes be changed in order to better facilitate learning about a Strategic Sustainable Development approach? If so, how?

**Research Scope and Limitations**

The research specifically centered on the process of the Challenge Prize and how the process enables the participants to learn and implement the learned content. The research did not cover other interesting areas of Challenge Prizes, although we acknowledge that they might impact the process.

**Methods**

This research was conducted based on a Qualitative Research Design. In order to better shape our research questions and process, we conducted exploratory interviews with Challenge Prize organizers. First three exploratory interviews were conducted and an analysis was conducted using the FSSD to organize the information from the interviews and literature, in order to identify research gaps. Based on that, we developed interview questions. The data collection was via qualitative semi-structured interviews with SSD experts, PBL experts and Challenge Prize organizers. The data from the interviews was processed through coding. The coded data was combined into themes, in which there was a main concept and related variables that emerged from the three data sources in relation to learning. We created visualization in form of a scale of 0-10 for each variable in order to understand how it was actually present in the Challenge Prizes. This process helped us to understand what aspects of learning are currently present in Challenge Prizes and how those aspects could be improved to create space for learning SSD. The analysis helped to make sense of the data in order to answer all of our research questions.

**Results**

The coded information was combined in 13 themes: Characteristics of the problem or the challenge, Methods of teaching, Learning process, Feedback, Core concepts of sustainability in a Challenge Prize, Assessing sustainability, Experimentation, Group work and collaboration, Group work environment, Mentors and experts, Learning in a competitive environment, Diversity and Supporting participants in finding information, in which 39 variables related to learning were found. The results showed that some of the interviewed Challenge Prizes have as their purpose to enhance participants' learning and they are already adopting practices to achieve this goal. However, there are gaps in relation to what the SSD and PBL experts mentioned as good conditions and practices for learning and what actually occurs in the Challenge Prize process. Secondly, there were findings about the differences between PBL theory and its actual application to learning processes and how the PBL stages relate to current stages of Challenge Prizes. Finally, it was noticed that the majority of Challenge Prizes do not adopt a clear definition of sustainability. They also do not include similar concepts to the core SSD concepts.

**Discussion**

**How do Challenge Prizes facilitate learning?**

About half of the Challenge Prizes that were interviewed had learning as one of their goals. However, only some of these offered support for the learning process of the participants. Interviewed Challenge Prizes that most emphasized the competitive nature of the prizes, also offered least support for the participants for their learning process. Some Challenge Prizes had incorporated learning opportunities for the participants so that they could create better solutions (e.g. by offering challenge related information or supporting the development of practical skills), even if they did not state learning as their overall goal.

We identified several practices in Challenge Prizes that facilitate learning. Some of the practices are an innate part of every Challenge Prize process while others are added in the design by organizers in order to foster participants' learning. Innate areas of every Challenge Prize process that foster learning are group work, collaboration, bringing together diverse groups of stakeholders, creating and developing an idea and learning by assessing a solution. In addition to these learning aspects that are shared by all Challenge Prizes, some organizers offer opportunities to learn through providing information and expertise that is related to their challenge, for example by providing workshops.

It would be helpful for the organizers to be aware of PBL and other learning theories, in order to better incorporate learning through areas identified in this research. It was clear for the researchers that the Challenge Prizes could benefit from recommendations in order to better support learning. Specific opportunities for improvement included supporting group work in different ways, creating the learning process in a structured and iterative way, using varied methods of teaching, providing reflection opportunities, supporting idea creation and development and supporting diversity and collaboration among participants in a more effective manner.

**In what ways could the learning process of sustainability-oriented Challenge Prizes be improved by a rigorous application of Problem-based Learning?**

Challenge Prizes naturally rely on Problem-based learning, since the Challenges are centered on a real-life problem that the participants are trying to solve. The learning experts generally do not follow the PBL approach rigorously when designing the learning experiences, but

instead use the PBL approach more as an inspiration. The gaps and opportunities for improvement related to PBL that emerged in the research, are related to the support that the organizers can offer to the participants in their group processes and in the development of the solution. It was found that the organizers could support the participants in different ways, by for example: providing mentors to guide the participants through the process and external experts to support with specific content; as well as by developing the right conditions for collaboration, offering support for group work and including reflection and feedback practices.

**Could the learning processes of sustainability-oriented Challenge Prizes be changed in order to better facilitate learning about a Strategic Sustainable Development approach? If so, how?**

In this research, we identified conditions that are favorable for learning SSD. As explained before, Challenge Prizes already offer some of these conditions in varying degrees. The participants should have an opportunity to learn the SSD concepts and the SSD approach should be embedded in the design of the Challenge Prize, through the setting of the challenge and creation of the winning criteria. The Challenge Prize process would include SSD in five levels as seen with an analysis through the FSSD. The SSD would be taken into account while setting the challenge so that the challenge is understood as part of the larger socio-ecological system, allowing the participants to understand the interconnectedness of the system. The Success level would comprise of the winning criteria that include the Sustainability Principles and any other criteria deemed important by the organizer. The Strategic level would allow the participants to backcast from the winning criteria as it would be communicated to the participants. The Actions level would consist of the different actions that help creating a learningful process for the participants, for example the participants should be supported with feedback. On Tools level the participants would be offered tools that help them assess the sustainability of their ideas.

**In what way could sustainability-oriented Challenge Prizes, supported by Problem-based Learning, help facilitate learning for Strategic Sustainable Development?**

According to this research, sustainability-oriented Challenge Prizes can create positive change towards sustainability in two ways: by growing capacity in people towards moving society to a sustainable future and by creating solutions that are aligned with the SSD approach.

In order to address the Sustainability Challenge, there is a need for new ways of thinking and for an approach that can help dealing with the complexity of the challenge. SSD is an approach that proposes a clear definition of sustainability, based on principles, and that incorporates concepts such as systems thinking and a framework that are helpful when addressing complex problems.

Learning for sustainability requires deep learning and alternative approaches that allow for cross-disciplinary thinking. PBL is an approach with these characteristics and is also already implicitly found in Challenge Prizes. Therefore, they could benefit from incorporating it in order to design an effective learning process.

Having a sustainability-oriented Challenge Prize that is structured around a pedagogical approach that allows the participants to implement the theory into a practical solution will help them to gain skills and knowledge about SSD. Also, a structured learning process could benefit both the participants in their learning process and the Challenge Prize organizers, due to the higher likelihood of more innovative and better solutions.

Learning in Challenge Prizes is different from traditional education and can engage people that would not be interested in taking part in courses or formal education about sustainability.

**Conclusion**

There is an imperative need to understand the sustainability challenge and to learn ways to address it. Sustainability-oriented Challenge Prizes are an environment that has potential to address the Sustainability Challenge, since they offer a space for addressing the Sustainability Challenge through learning, while also holding potential to produce sustainable solutions as an outcome. They already incorporate many aspects that are needed for learning sustainability, for example diverse participants and an interdisciplinary environment. In order to foster deeper learning about sustainability they should incorporate SSD, so that the participants will be able to understand the complexity of the Sustainability Challenge, adopt a systems perspective and be offered a clear definition for sustainability. In order to further enhance learning for sustainability, the learning processes could be improved by the application of PBL followed loosely.

The outcome of this research was to produce recommendations to the Challenge Prizes organizers that wish to include learning for sustainability. We hope that the Challenge Prizes organizers use this information to create processes for sustainability-oriented Challenge Prizes that will enable the participants to learn about SSD and create more sustainable solutions. Hence, supporting society on the move towards a sustainable future.

# List of Abbreviations

BTH          Blekinge Institute of Technology

FSSD        Framework for Strategic Sustainable Development

GC           Green Challenge

NC           Nordic Built Challenge

PBL         Problem-based learning

R&D         Research and Development

SBC         Solar Challenge Brazil

SD           Sustainable Develpment

SA           SIA Austria

SC           SIA Czech Republic

SPs         Sustainability Principles

SSD        Strategic Sustainable Development

TNS        The Natural Step

TV           Technovation

XP           XPrize

WP          Wege Prize

# Glossary

Anthropocene - A new era, in which the human influence on the Earth's system is greater than the natural forces.

Backcasting - A strategic planning method that is based on creating a vision of a desired future and the gaps between it and the current reality. .

Challenge Prize - Challenge Prizes offer a reward to anybody who can first or most effectively meet a defined challenge.

Challenge Prize Process – Process, which the participants go through, of the competition from the launch until the awarding of prize.

Challenge Prize participant - A person attending a Challenge Prize as a contestant.

Challenge Prize organizer - An organization or individual that is responsible for the practical organization and planning of the Challenge Prize.

Complex Adaptive System - In the system all parts are interconnected and no part is more important than the other, there is a constant flow of energy and matter through the system and the system has a self-organizing nature.

Experimentation - to try out or test a developed idea.

Framework for Strategic Sustainable Development - A conceptual model based on scientific foundations. It provides an approach to move strategically towards sustainability.

Problem-Based Learning - A learning approach that revolves around solving a problem.

Research and Development (R&D) - Any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications.

Sustainable Development - Development that allows people to meet their own needs without compromising the possibility for other people to meet their own needs, now and in the future.

Strategic Sustainable Development - Scientific and strategic approach that allows for planning to move towards a sustainable future.

Strategic Experiment - Doing something new in a given context through concrete actions and with a limited scope, with the intention of influencing the society as a whole.

Systems Thinking - An approach of understanding how systems relate and influence each other, and how the properties of the parts can only be understood through the dynamic of the whole.

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# 1 Introduction

This research explores the role that sustainability-oriented Challenge Prizes could play in addressing the Sustainability Challenge the Earth currently faces. Challenge Prizes are contests that offer rewards for individuals or organizations that can develop a solution for a defined challenge (Ballantyne 2014). Challenge Prizes have a long history in helping humankind invent solutions to complex problems in different societal fields; from space technology to agriculture (Masters and Delbecq 2008).

One outcome of Challenge Prizes which is often overlooked is that they can function as environments for learning (McKinsey and Company 2009). Additionally, we see Challenge Prizes as environments that implicitly use Problem-based Learning, since during the contest the participants apply their knowledge to create a practical solution for a defined problem.

This research explores how the learning experience within Challenge Prize processes could benefit from applying a Problem-based Learning approach and a wider understanding of sustainability through the Strategic Sustainable Development approach.

## 1.1 Sustainability Challenge

In the last 100 years, human population increased from approximately one billion to six billion (Steffen et al. 2004) and it is estimated that by the year 2050 the population will have exceeded nine billion (United Nations 2011). With the global population increasing, human activities and negative impacts on the socio-ecological system have also expanded (Steffen et al. 2004). Researchers argue that this poor management of the Earth's resources pressures the ecosystems and has critical and uncertain consequences for future generations (UNEP 2012). Researchers argue the way our society currently operates is undermining basic conditions for all life on Earth (Steffen et al. 2004). Moreover, given the Earth's resources are finite, this increase in population and related impacts directly contribute to the Sustainability Challenge (Holmberg et al. 1999; Broman et al. 2000; Phillis and Andriantiatsaholiniaina 2001; Merkel and Litten 2007).

In order to try to comprehend and visualize the challenge, the Planetary Boundaries concept was developed by Steffen et al. (2004). The Planetary Boundaries attempts to represent global priorities related to human-induced changes to the environment and thus, define a safe operating space for human societies. The research indicates four of the nine boundaries have been crossed as a result of human activity. They are: climate change, biosphere integrity, land-system change, and altered biogeochemical cycles (phosphorus and nitrogen) (Steffen et al. 2015). The climate change and biosphere integrity boundaries are of special concern as they are considered to be core boundaries and the crossing of them could drive the Earth into a new state as a system (Steffen et al. 2015).

This and other related research has led scientists to argue Earth has entered the Anthropocene, an era in which the human influence on the Earth's system is greater than natural forces (Arias-Maldonado 2013; Biermann 2014; Steffen et al. 2015). This new era is likely to be more inhospitable to the development of human societies (Steffen et al. 2015). Also, Earth is now considered to be operating in an unprecedented state, in which multiple, complex, interacting, and globally significant changes happen due to human activities at an exponential rate (Steffen et al. 2004; Biermann 2014).

A metaphor that helps to envision what unsustainability represents to life on Earth is a funnel. The narrowing funnel walls represent the global trends that lead to unsustainability. Society is moving towards the narrower part of the funnel, where the capacity of Earth to sustain life is reduced, the capacity of self-renewal is decreased and the space for maneuvering is limited (Broman et al. 2000; Ny 2006; International Union for Conservation of Nature 2006). Organizations and other social systems that make uninformed choices based on an incorrect mindset that the resources are infinite or that there are no negative threats due to their increased use, will sooner or later hit the funnel walls (Ny 2006). Hitting the walls represents different consequences such as higher taxes, higher costs for waste management, higher costs for resources, among other issues (Robèrt 2000). For society to avoid hitting the walls of the funnel, it needs to adopt sustainable practices that stop the continued narrowing of the funnel walls and help to move society towards a sustainable future. This is represented in image 1.1.
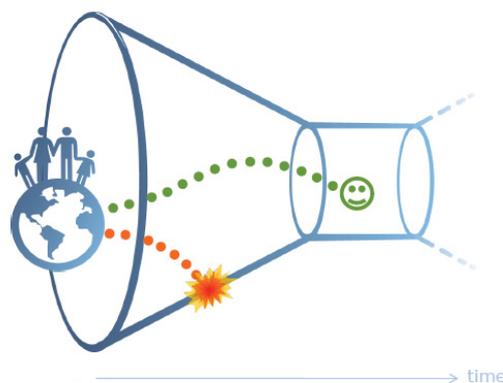


*Image 1.1The Funnel (Adapted from Robèrt 2000, 246)*

One of the reasons for the narrowing of the funnel walls is the current economic system and the businesses within it. The majority of business organizations have adopted a model of constant growth that does not seem to be appropriate (Porter and Kramer 2011). This causes organizations and society at large to hit the walls of the funnel. Additionally, competition is a part of the current economic system in which companies want to grow while saving money in order to stay competitive in the market (Porter and Kramer 2011).

Competition has globally affected people's lives in different negative ways, for example leading to lower wages and reduction of employment opportunities (Glass and Saggi 2001), as well as environmental destruction and economic distress (Porter and Kramer 2011). However, it has also positive impacts. For example, competition has been long considered a source of creativity that allows for some forms of cooperation (Jacquemin 1995).

As shown in this section, the sustainability challenge is composed of different aspects that are related to economy, environment and social problems. Therefore, it can be considered a complex problem (Peter and Swilling 2014). The understanding of the dependence of human life on the environment, rather than its dominance over it, led to the awareness of the connection and interdependence between environmental and socio-economic issues. Thus, the concept of Sustainable Development (SD) was born (Hopwood, Mellor and O'Brien 2005).

## 1.2 Sustainable Development

### 1.2.1 Defining Sustainable Development

Sustainable Development refers to a process in which human well-being is maintained or improved without eroding the socio-ecological system in the present and in the future. The most famous definition of SD is from the Brundtland report which states that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). This definition will most likely continue to be widely cited (Tainter 2006). However it has received a lot of criticism due to its vagueness, limited operational usefulness, impreciseness and complexity (Jacobs 1999; Phillis and Andriantiatsaholiniaina 2001; McKenzie 2004; International Union for Conservation of Nature 2006; Tainter 2006; Missimer 2013). For example, Jacobs (1999) stated that this vagueness allows people to say that they are in favor of sustainable development while in reality they are contributing to unsustainability. Research has also shown that sustainability is considered too abstract and broad because of its large scope and lack of a clear definition (Allen and Hoekstra 1994; Leal Filho 2000; International Union for Conservation of Nature 2006).

### 1.2.2 Tools to approach Sustainable Development

Considering that the Sustainability Challenge is complex and that there is a lack of agreement on an operational definition for sustainable development, different tools have surfaced in order to address these problems (Robèrt et al. 2002). Examples of these tools are ISO 14001, Life Cycle Assessment, Factor X, and Ecological Footprint (Weizäcker, Lovins and Lovins 1997; Holmberg et al. 1999; MacDonald 2005; Porter and Kramer 2011). It is clear that there is a broad range of approaches, tools, frameworks, strategies, principles and processes that can help organizations move towards sustainability (MacDonald 2005). However, it is argued that many of the tools mentioned above lack a clear definition of sustainability as they are not defined by principles (Mitchell 1996).

Organizations need a clear framework to be able to move towards a sustainable society (MacDonald 2005). Also, in order to select and create tools to monitor the progress towards sustainability, tools should be built on a specific and clear definition of sustainable development rather than a vague one (Holmberg et al. 1999).

## 1.3 Strategic Sustainable Development

The tools mentioned above attempt to help address certain aspects and symptoms of the Sustainability Challenge. However, they do not address the whole challenge in a holistic manner. In order to address this gap, a strategic and scientific approach called Strategic Sustainable Development (SSD) was developed (Robèrt 2000; Broman et al. 2000; Robèrt et al. 2002; Ny et al. 2006). SSD is based on a systems thinking approach as it strongly recommends that a whole systems perspective is used when analyzing sustainability related challenges and opportunities. This allows people to better understand the complexity of the Sustainability Challenge.

Strategic Sustainable Development addresses the lack of agreement with an operational definition for sustainability by having eight Sustainability Principles (SPs), which provide boundary conditions within which humanity can create a sustainable society. The eight Sustainability Principles are:

In a sustainable society, nature is not subject to systematically increasing...

...concentrations of substances extracted from the Earth's crust,

...concentrations of substances produced by society,

...degradation by physical means (Ny et al. 2006).

and...people are not subject to systematic barriers to…

... personal integrity,

... influence,

... competence,

... impartiality,

... meaning (Missimer 2013).

Researchers believe these eight principles provide a clear definition of what is required to achieve sustainability. Additionally they are considered to be operational as they can indicate a clear way towards progress, and overall success. This allows for a strategic planning towards sustainability since the principles can help to create a clear vision of a sustainable future (Robèrt 2000; Broman et al. 2000; Robèrt et al. 2002; Ny et al. 2006).

Having a clear vision of success is considered by many researchers to be the first step when planning strategically. To continue with the planning process, it is also helpful to use a conceptual framework that helps simplify the complexity of the Sustainability Challenge. The Five Level Framework for Planning in Complex Systems was adapted to help to move towards sustainability by adopting the approach of SSD. The adapted framework is called Framework for Strategic Sustainable Development (FSSD) (Holmberg and Robèrt 2000; Ny et al. 2006).

The FSSD includes five levels: System, Success, Strategic, Actions and Tools. In the System level, it is required to have an understanding of the socio-ecological system and the Sustainability Challenge. The Success level is defined by the constraints of the eight sustainability principles. The Strategic level is about backcasting from the vision of success, and using strategic guidelines that will help guide actions towards success. In the Actions level, the steps to move towards the vision are determined. The last level includes tools that may help the overall planning endeavor (Holmberg and Robèrt 2000; Ny et al. 2006).

It is important to note that the FSSD is not a measuring tool and in order to see if society is moving towards sustainability, other tools should be used and selected with the guidance of the FSSD. It is also useful to note that there are certain situations in which there is no need for strategic planning and that strategic planning does not always lead to the best result (Ingenjörer för Miljön 2008).

## 1.4 Learning Sustainable Development

As mentioned before, the Sustainability Challenge is complex (Peter and Swilling 2014) and it requires reflection and social learning in order to address it effectively (Hjorth and Bagheri

2006). There is a need for new ways of thinking in order to contribute to society's move towards sustainability (Hjorth and Bagheri 2006) and this can be achieved through education.

It is accepted in the literature that education for Sustainable Development requires systems thinking and interdisciplinary approach (Cartese 1992; Buckingham-Hatfield 1996). Sustainability problems "require flexible, integrative, multidisciplinary problem-solving approaches, rather than singular solutions" (Steinemann 2003, 218). Researchers also mentioned that deep learning is essential in this field, since there is a need to have a holistic perspective as well as an ability to make sense of different types of information, creating a coherent whole. Differently from surface learning that has a strong descriptive aspect; deep learning is about finding underlying meaning, developing analytical skills and independent thinking. In this sense, "Deep learning can be encouraged by emphasizing principles and concepts rather than accumulated facts" (Warburton 2003, 48). The need for systems thinking and emphasis on principles and concepts are related to the characteristics of SSD, which seems to be an appropriate approach to teach when seeking to enhance deep learning for Sustainable Development.

Finally, literature refers to the fact that the university community has had difficulties in adopting these characteristics and that there is a "need for innovative educational approaches that facilitate real cross-disciplinary thinking" (Warburton 2003, 44). There is a learning approach called Problem-based Learning that seems to be an appropriate approach since it enhances deep learning, by relying on collaboration between transdisciplinary groups, independent learning and analytical thinking.

## 1.5 Problem-based Learning

Problem-based Learning (PBL) is a learning approach that seeks to create a link between theoretical knowledge and practice (Cockrell and Caplow 2000). This approach is based on the concepts of Lev Vygotskian about Social Development Theory, which considers learning as a social construction of knowledge (Beringer 2007). PBL involves a transdisciplinary approach, collaboration, diversity and an iterative nature in the learning process (Stepien and Gallagher 1993; Alavi 1995; Cockrell and Caplow 2000).

Another characteristic of PBL is that the given problem should be complex and ill-structured, meaning that it should not be easily or formulaically solved and that it can have more than one single solution. The problem should also be real. By using real problems that are relevant to society, researchers argue it is possible to develop higher levels of comprehension and skills than in a traditional learning setting (Awang and Ramly 2008).

PBL makes knowledge more accessible and applicable, since the need to apply abstract concepts to develop a solution, makes these concepts more relevant and meaningful to the learners (Steinemann 2003). The dual format of PBL encompasses individual and group aspects, requiring active participation and discourse around the topic. The result of this is the development of communities of practice, and ownership of knowledge (Cockrell and Caplow 2000; Awang and Ramly 2008). Additionally, PBL recognizes nothing can be learned in totality and that learning needs to be shared among transdisciplinary groups (Missimer and Connell 2012). It is essential to have collaborative groups in learning contexts; to explore, analyze and solve the problems presented (Cockrell and Caplow 2000).

All of the characteristics outlined above show how PBL can be highly effective to address complex problems like the sustainability challenge. In fact, research shows most successful PBL approaches deal with complex problems (Beringer 2007).

## 1.5.1 The PBL process

The PBL process has two main components: the tutor and the group of students. The tutor acts more like a good facilitator than a content expert. The role of the tutor is focused on building good learning strategies and monitoring the process (Hmelo-Silver 2004). Regarding the group of students, literature on collaborative work shows that effective collaboration happens in groups from two to twelve people. Number of members in a group should be decided according to the complexity of the problem and to the scale of the solution required. Groups should be diverse, since this aspect resembles working situations that the students will face after their education program (Speck 2003).

When applying PBL, the problem-solving process involves five steps:

1. Observation or information gathering: The problem scenario is presented and it is expected that the students identify facts around the given problem to create a good level of understanding of it (Cockrell and Caplow 2000; Hmelo-Silver 2004; Beringer 2007).
2. Questions, ideas and hypothesis formulation: the students use their prior knowledge and experience to identify the assumptions and questions they may have. They formulate their questions, ideas and hypotheses related to the solution of the problem (Cockrell and Caplow 2000; Hmelo-Silver 2004; Beringer 2007).
3. Learning issues/inquiry strategy: The students identify their knowledge deficiencies and define the learning gaps that they will need to explore by themselves. At this point, the students can collaborate with others, within and outside the learning situation to fill in the gaps of understanding (Cockrell and Caplow 2000; Hmelo-Silver 2004; Beringer 2007).
4. Action Plan: The students integrate the new knowledge on the results of the second phase and then proceed to the development of a solution (Cockrell and Caplow 2000; Hmelo-Silver 2004; Beringer 2007).
5. Reflection: The students reflect on the abstract knowledge gained. This phase also appears during other phases of the process. In the end, it is important for them to also reflect on the skills gained and in the collaborative aspect of the process (Cockrell and Caplow 2000; Hmelo-Silver 2004; Beringer 2007).

It is important to note reflection is a critical component of PBL as it helps the students to "identify gaps in their thinking; and transfer their problem-solving strategies, SDL *(self-directed learning)* strategies, and knowledge to new situations" (Hmelo-Silver 2004, 247).

In learning literature, it is acknowledged that feedback has an important role for facilitating recognition of deficiencies in knowledge and skills. However, this aspect is not well explored in the PBL literature, although some studies show that it can be useful to improve learners' skills (Parikh, Mcreelis and Hodges 2001).

Considering the aspects above, PBL can be seen as an approach that facilitates deeper learning by allowing the learners to put theory into practice, while relying on independent learning and analytical thinking. Also, the learners are involved in a diverse environment that is favorable for collaboration and for dealing with complex and transdisciplinary problems, such as issues of the Sustainability Challenge. Therefore, we believe PBL would be appropriate for facilitating learning about sustainability, as also stated by researchers Missimer and Connell

(2012). The university community seems to be failing in enhancing learning about sustainability (Warburton 2003) and there are alternative learning spaces that could be improved by PBL. Due to its similarities to real life settings, PBL can resemble non-traditional learning environments such as Challenge Prizes.

## 1.6 Challenge Prizes

Challenge Prizes are contests, in which a reward is offered to anybody who can first or most effectively meet a defined challenge (Kalil 2006; Ballantyne 2014). Challenge Prizes are organized by public institutions, companies or NGOs, in order to crowdsource innovation, reaching out of closed communities of employees, contractors and grant recipients (Knowledge Ecology International 2008). Challenge Prizes are research and development (R&D) activities, that can fulfill similar societal purposes in supporting innovation as government funding, intellectual property rights or education (Kalil 2006; Ballantyne 2014).

The history of Challenge Prizes is long. In the past, Challenge Prizes were used to create major scientific and technological breakthroughs (Masters and Delbecq 2008). One historical example of Challenge Prizes includes the 16th century Longitude Prize, which offered a reward for the person who could provide a way for more accurate navigation (Masters and Delbecq 2008). Challenge Prizes have enjoyed a renaissance in the past years with some recent and very influential Challenge Prizes (Kalil 2006). Their renewed and strengthened ability to affect positive change is considered to be one of the fundamental reasons for this renaissance (McKinsey and Company 2009).

Challenge Prizes have many features of PBL even if PBL is not intentionally included in them. For example, the process of a Challenge Prize revolves around trying to solve a real-life problem, which results in the participants learning new skills. Furthermore, Challenge Prizes are a tool that is considered to be suitable to address the sustainability challenge considering the innovations and societal change they can bring forth (Masters and Delbecq 2008). Here are some of the characteristics of Challenge Prizes that are similar to the PBL approach and can be considered to be suitable to address the Sustainability Challenge.

1. Challenge Prizes have an ability to bring together powerful networks and enable members to collaborate, share ideas and best practices, and therefore strengthen a community and encourage future collaboration and innovation (McKinsey and Company 2009). This is seen as essential in PBL (Hmelo-Silver 2004) and when dealing with the Sustainability Challenge (Hjorth and Bagheri 2006).
2. Challenge Prizes engage participants with a real life problem and create a setting that resembles the real world, in terms of the cross-fertilization of knowledge (McKinsey and Company 2009). This is highly important since the complexity of the Sustainability Challenge requires flexible solutions and not merely theoretical ones (Steinemann 2003), which is also similar to the PBL characteristics (Cockrell and Caplow 2000; Beringer 2007).
3. Challenge Prizes most often deal with complex challenges (Ballantyne 2014). The problems in PBL should also be complex (Hmelo-Silver 2004) and the Sustainability Challenge is complex (Peter and Swilling 2014).
4. Challenge Prizes help to attract and identify diverse talent and create unexpected approaches and cross-disciplinary solutions (McKinsey and Company 2009). In PBL groups should also be diverse (Speck 2003) and foster a transdisciplinary approach (Missimer and Connell 2012), which is also important when addressing the Sustainability Challenge (Steinemann 2003).

The similar characteristics between Challenge Prizes and PBL that are relevant to address the Sustainability Challenge are summarized in table 1.1.

| | Sustainability Challenge | PBL | Challenge Prizes |
|---|---|---|---|
| Characteristics related to collaboration | Collaboration is important for solving it | Collaboration is important for solving the problem | Often collaborative |
| Characteristics related to real-life problems | Real life problem | Real life problem | Real life problem |
| Characteristics related to complex problems | Problem is complex | Problem is complex | Problem is often complex |
| Characteristics related to diversity | Diversity is important for solving it | Diversity is important for solving the problem | Potential for diverse teams and diverse solutions |

*Table 1.1Features of Challenge Prizes and PBL suitable to address the Sustainability Challenge*

Given the suitability and similarities between Challenge Prizes and PBL, we are interested in how combining the two concepts could be used as a way to deal with the Sustainability Challenge. As stated before, in order to accomplish this, there is a need to learn new ways of thinking, which we believe can be achieved by enhancing learning about SSD in the Challenge Prizes related to sustainability issues.

## 1.6.1 Benefits and Limitations of Challenge Prize in Innovation

The importance of Challenge Prizes and their proliferation in the past 50 years is due to the possibility of introducing path-breaking innovations and engaging new social groups to form communities who can invent solutions to a wide range of problems (Kay 2011). Challenge Prizes can shine light on especially challenging problems in society, or provide major breakthroughs in human knowledge (Ballantyne 2014). This shows how Challenge Prizes could be used to work with big, complex challenges like the Sustainability Challenge. Attracting different types of participants is also a benefit of the Challenge Prizes, since they can attract both traditional institutionalized companies and smaller players that are less risk averse and can therefore pursue more radical solutions (Nalebuff and Stiglitz 1983; Schroeder 2004; Culver et al. 2007; Kay 2011).

Challenge Prizes are especially beneficial in the following situations:

1. A goal can be defined in concrete terms but the means of achieving that goal are too speculative to be reasonable for a traditional research program;
2. The organization setting the prize wishes to be non-prescriptive about who is in the best position to meet it;
3. The organization setting the prize wishes to only pay when somebody meets the predefined objective;
4. There are additional benefits about attracting the attention of media and wider public;
5. The organization setting the prize wishes to attract novel innovators and entrepreneurs with new ideas to tackle the challenge (Kalil 2006).

Even if there are benefits to innovating with Challenge Prizes, some drawbacks related to innovation with prizes have been identified by researchers. For example, Challenge Prizes are useful only in a limited range of innovation situations, and may only attract certain types of participants. A practical hindrance is the fact that the small and medium sized organizations that compete in Challenge Prizes may find it difficult to come up with necessary funds to create solutions (Kalil 2006), and also the participants need to be motivated to invest time in participating. It may also be difficult to find participants who actually have the right expertise to solve the challenge and who are willing to invest unpaid time for it. Challenge Prizes are not an effective tool for innovation in cases which there is no clear and achievable goal (McKinsey and Company 2009). It has also happened in the history of Challenge Prizes that the challenge in certain contests has been too difficult and therefore the reward has never been awarded (Purewal 2015).

Other problematic issues with Challenge Prize innovation are related to the performance of the participants. The so called patent race phenomenon refers to a situation in which all prize participants use similar methods to achieve the Challenge Prize goal and thus develop solutions that are in fact very much like each other (Masters and Delbecq 2008). The design of the contest creates another kind of limitation: the goal sets a threshold for achievement, which makes it impossible to know anything about performance with more or less ambitious goals (Masters and Delbecq 2008). Also, the prize design with a preset goal may limit the creativity of the solutions offered, since it is impossible to know, whether some participants could have developed effective solutions to problems that are closely related but slightly different from the given Challenge Prize goal (Masters and Delbecq 2008). So there is a risk with Challenge Prizes that the solutions created are not the best possible ones for the particular challenge, and actually in many cases more traditional research and development programs can bring better results.

## 1.6.2 Challenge Prize Design and Process

As mentioned above, Challenge Prizes are typically organized as competitions that have rules that aim at achieving a solution or breakthrough to a certain challenge within a deadline. Each Challenge Prize creates a unique design based on its goals (Kay 2011).

The Challenge Prize process is defined as the process of the competition, from the launch until the awarding of the prize (Ballantyne 2014). Some Challenge Prizes do not have a specific process, since no interim support is offered to the participants (Ballantyne 2014). On the other hand, other Challenge Prizes have a process in which they include different types of support for the participants, for example skill training, networking opportunities or interim prizes (Ballantyne 2014). The process of Challenge Prizes has the potential to create a space for experimentation, fostering more effective solutions (McKinsey and Company 2009) and benefiting from a variety of ideas that come from several participants.

A well-designed and well-run process attracts quality participants, captures attention, passion, and innovation through competition, celebrates winners and ensures maximum impact for the prize (McKinsey and Company 2009). McKinsey and Company (2009) argue in their research that an effective Challenge Prize process is important, since it reinforces the strategy of the prize. The Challenge Prize processes are not well investigated in academic research.

## 1.6.3 Challenge Prize Process and Learning

Besides the fact that the Challenge Prize process aims to result in a valuable solution, it can also influence the participants to learn new skills. The fact that the Challenge Prizes often

improve the skills of the participants is viewed as a welcome by-product of the competitive process (Hussmann, Trandum and Vigild 2010). In fact, some Challenge Prize organizers consider the process of the contest to be at least as important as the outcome, and developing the skills of the participants is a principal goal of the program (Hussmann, Trandum and Vigild 2010). This is especially true for Challenge Prizes that engage young participants (McKinsey and Company 2009).

Even though Challenge Prizes have the possibility to teach new skills to the participants, in the McKinsey and Company research from 2009, only 35% of Prize organizers actively sought to educate and improve the skills of participants.

## 1.7 Relevance of the Research

Learning is crucial for the new societal change that is needed to address the Sustainability Challenge (Hjorth and Bagheri 2006) and traditional education settings seem to be insufficient for that (Warburton 2003). Challenge Prizes can be seen as an alternative learning space that can offer a creative and collaborative environment for learning sustainability in new way.

There are many sustainability-oriented Challenge Prizes (Nesta n.d.; Sustainergies n.d.; Dow n.d.). However, there is a gap regarding the way Challenge Prizes are currently trying to address the Sustainability Challenge. As Kalil (2006) argues, in energy and climate change themed prizes, it is difficult to define the victory conditions as the definition of success is not clear. Therefore, we believe that a clear, scientific and operational definition of sustainability could help define the victory conditions for sustainability-oriented Challenge Prizes.

Another important aspect that makes this research relevant is the fact that academic research has not investigated Challenge Prizes thoroughly despite their long history, recent popularity, and notable potential (Kay 2011). The research in the field of Challenge Prizes has largely concentrated on the impact of the prizes, and their role as inducing innovation and completing other innovation acceleration methods (e.g. Fu and Lu 2009; Brunt, Lerner, and Nicholas 2012; Besharov and Williams 2012). Moreover, Challenge Prize processes are not a well investigated area, and neither is the learning that takes place in the process of the Challenge Prize.

Considering the stated importance of a good Challenge Prize process, the lack of research of this aspect and its potential to enhance learning about sustainability, we are exploring the Challenge Prize process from the organizers perspective. Specifically, we believe SSD can inform participants with a clear definition of success and a strategic approach. Therefore, we are interested in researching how sustainability-oriented Challenge Prizes can facilitate learning of SSD during their process. Furthermore, SSD is an approach that is helpful when finding solutions to the Sustainability Challenge since it includes systems thinking and a planning framework. In order to enhance deep learning about it, PBL seems to be an appropriate approach. Additionally, given the similarities of PBL and Challenge Prizes, we see an opportunity for Challenge Prizes to deliver better learning experiences by applying a more rigorous PBL approach.

## 1.8 Purpose

This research aims to investigate how sustainability-oriented Challenge Prizes could implement a more rigorous Problem-based Learning approach and include learning for Strategic Sustainable Development in their process.

### 1.8.1 Research Questions

Primary Research Question:

- In what way could sustainability-oriented Challenge Prizes, supported by Problem-based Learning, help facilitate learning for Strategic Sustainable Development?

Secondary Research Questions:

- How do Challenge Prizes facilitate learning?
- In what ways could the learning process of sustainability-oriented Challenge Prizes be improved by a rigorous application of Problem-based Learning?
- Could the learning processes of sustainability-oriented Challenge Prizes be changed in order to better facilitate learning about a Strategic Sustainable Development approach? If so, how?

### 1.8.2 Scope and Limitations

The research is specifically centered on the process of the Challenge Prize and how the process enables the participants to learn and implement the learned content.

The research does not cover other areas of Challenge Prizes including the impact or future development of the solutions after the contest, the process of creating the challenge and setting the prize, the way the Challenge Prize is communicated to create public awareness, the motivation of the participants, or how the criteria for winning is created. Although we briefly acknowledge many of these aspects in this research.

# 2 Methods

## 2.1 Overall Research Design

For this thesis, we decided to use a Qualitative Research Design as it enabled the gathering of rich, deep data, allowing for contextual understanding, concerning the point of view of the interviewees and working with meaning (Sachdeva 2009; Bryman and Bell 2011). Additionally, Qualitative Research Design is appropriate for exploring topics that researchers are not intimately familiar with and it is considered to be well suited for topics where there is a general lack of research (Bryman and Bell 2011). Therefore, it seemed appropriate for our topic given the process of Challenge Prizes has not been explored in depth by academic literature.

In order to better shape our research questions and process, we conducted exploratory interviews with professionals from institutions who organize Challenge Prizes. The aim of the interviews was to gain an overall understanding of the field of Challenge Prizes. By doing this, we were able to identify the research gap and shape better research questions. We interviewed organizers from three Challenge Prizes: Innonatives, Students Competitions and Challenge Prize Brazil. We chose them based on the differences of their processes and on the level of maturity of the project. An overview of their characteristics can be seen in Appendix A.

## 2.2 Research Process

Based on the information gathered through the exploratory interviews and through reviewing the literature, we did an analysis to identify the gaps of information that we needed to fill in order to answer our research questions. We decided to use the Framework for Strategic Sustainable Development (FSSD) in order to organize this information in a clear and structured way. To do this effectively, we mapped different aspects of SSD, PBL and Challenge Prizes processes according to the levels of the FSSD. The information gaps identified were used to formulate the interview questions. This analysis can be seen in Appendix B.

The research process started with data collection, which was conducted in two stages. First, we interviewed learning experts, followed by a second stage of interviews with Challenge Prize organizers. Data from the interviews were analyzed through a qualitative thematic analysis in order to answer the research questions and to create some recommendations to the Challenge Prize organizers.

### 2.2.1 Data Collection

To answer the research questions, we conducted qualitative semi-structured interviews. The interviews were formulated based on a general interview guide approach. This approach was chosen as it provides flexibility to build subsequent questions on the former answers (Turner 2010). Moreover, semi-structured interviews are a useful approach when there is one opportunity to interview somebody, and there are several interviewers collecting data (Savin-Baden and Howell Major 2013) as it was in the case of this research. Also, this approach assured that information was collected from all interviewees around the same general topics. To be able to see if the interview questions were clear and understandable, a test interview was conducted with an SSD practitioner who was not part of the research target group.

Interviews were conducted via Skype or face-to-face and had an average duration of 60 minutes. All the interviews were recorded in a Samsung smartphone. During the interviews, we followed the interview questions, which can be seen in Appendix C, and also explored the interviewees' perspective by using follow-up questions and distributing the time between the topics that felt most relevant. We all attended the interviews, except for two interviews in which one of the team members could not attend. In each interview one person was chosen as the main interviewer, while the other two researchers practiced active listening and asked additional questions. In the end, each of us conducted the same number of interviews.

The Research Questions of this thesis have two main aspects: the learning of SSD supported by a PBL approach, and how the Challenge Prizes facilitate learning. In order to understand both concepts in these aspects, we interviewed three groups of experts: SSD experts, PBL experts, and Challenge Prize organizers. Considering that each of these groups held different types of information that would answer different research questions, we had three different sets of interview questions.

We first interviewed the learning experts. By doing that, we aimed at validating some of our assumptions about learning before the interviews with the Challenge Prize organizers.

*Stage 1: Interviews with the learning experts*

We interviewed four SSD experts, one practitioner from The Natural Step (TNS), an NGO working with SSD, and three members from Blekinge Institute of Technology (BTH) teaching staff from the Master's program in Strategic Leadership towards Sustainability. They had teaching experience and also had used PBL in some way. By interviewing these experts, we gathered data that contributed to answer the questions regarding to how Challenge Prizes could incorporate learning about SSD and PBL. The interviewees were chosen due to their availability and experience with SSD concepts.

The second group of interviewees was experts with experience in teaching utilizing a PBL approach, one education developer from BTH, a teacher that uses PBL in the Department of Health of BTH and one learning designer from KaosPilot, a hybrid business and design school. The data from this source was mainly used to answer the second secondary research question, which refers to the possibility of applying PBL in a Challenge Prize context. These interviewees were chosen according to their availability and experience. A table with more details about the learning experts can be seen in Appendix D.

*Stage 2: Interviews with Challenge Prize organizers*

The second round of interviews was conducted with eight Challenge Prize organizers. These interviewees informed us about the design and characteristics of Challenge Prize processes. This group provided data to answer the first secondary research question about how Challenge Prizes can facilitate learning. This data was also used in order to compare and analyze how practices from the Challenge Prizes relate to what the learning experts mentioned about practices to teach SSD and use PBL.

The interviewed Challenge Prizes were chosen because we assumed they had a process for their participants that could contribute to their learning, and based on our judgment work with either social or ecological sustainability to some extent. We also considered the fact that they are from different countries and continents and that they had different processes and target groups. There was a conscious choice to focus the interviews to organizers, instead of interviewing participants of the Challenge Prizes. Specifically, we thought the organizers

would be able to bring in more understanding about the Challenge Prize process and design, giving an overview of the development of the contest. A table with additional information about the different Challenge Prizes can be seen in Appendix E.

### 2.2.2 Data Analysis

The recorded interviews were transcribed and the raw data was processed through coding. Each transcription was written by a researcher that was not the main interviewer for that interview.

The transcribed interviews were read by us to get familiar with the data and create the different codes. The codes emerged from the data. 46 codes were identified and placed on a coding matrix, as seen in Appendix F. The data was coded by the researcher that was neither the transcriber nor the main interviewer. Each coded section was copied and pasted to a new document, named after the code. Following this process, we had a discussion to verify if the coded sections represented the code or not. At this stage, the coded sections under each code were separated according to the different data sources (SSD experts, PBL experts, Challenge Prize organizers). When reviewing the coded information, we searched for larger patterns of meaning. This process was conducted with active discussion between us. The coded information was then combined into themes and separated under each theme according to the source. Each theme was then analyzed in order to confirm the data was supporting the theme. Also, in the process of refining the themes, some of them were combined or discarded, if deemed unimportant to answering the research questions. Finally, 13 themes were identified and a short description was written for each theme. This description aimed at clarifying the main concept behind the theme as well as the patterns identified between the different sources. The themes are presented in the results section.

In the process of building the themes, we identified smaller variables in the data source from the learning experts inside each theme; they were mostly related to what the learning experts consider necessary conditions for learning. Then we analyzed how those variables were actually present in the Challenge Prize processes, based on our perception. For the presentation of the variables we created scale visualization, with values from 0 to 10. The assignment of values was intuitive and based on our understanding of the data.

The Thematic Analysis helped to make sense of the data in order to answer all of our research questions. The data from learning experts was used to understand what is important for learning, and that information was used to analyze the Challenge Prize data in order to see the potential to learn about SSD and the possible changes that could be taken to raise this potential.

## 2.3 Validity and Triangulation

Researchers should choose the strategies best suited for the needs of their research to ensure the quality of the research (Savin-Baden and Howell Major 2013). To ensure a high degree of quality in this research, triangulation was achieved through having three researchers working on the project and also through reviewing the interviewee data through the websites of the interviewed Challenge Prizes and through documents sent by the interviewees.

The validity of this research was achieved through the researchers validating their decisions in the data analysis process by discussing the decisions and reviewing data that was analyzed by the other team members. We also extensively discussed all the codes and the themes that were constructed.

Other aspects that are important to consider for the validity of this research are the assumptions and biases held by the researchers. Since we had fairly similar values around collaboration, learning, innovation and sustainability, these values were likely to influence the research process. We believe in the potential of SSD and Challenge Prizes to create positive change in the world. We had similar educational backgrounds and two of us came from the same country, while one of us was from another country and continent, which contributed to different cultural perspectives in this research. To test and address some of these potential biases, we discussed all findings together employing different viewpoints.

## 2.4 Limitations of the Research

Limitations of the study are related to time constraints and interviewee availability. The research would have benefited from a longer duration of time, which would have enabled us to collect more data and use more varied data collection and analysis methods. We were also not able to interview all the experts that were contacted, since not all were available. However, we do not see this as a major limitation. Experts in qualitative research generally do not recommend to interview large numbers of people (Savin-Baden and Howell Major 2013) since a small sample of interviewees will usually give a thorough understanding of the subject, due to the qualitative nature of the data.

Also, a limitation that became apparent during the research was that not all the interviewed Challenge Prizes employed a process for their participants and some of the interviewees did not have a lot of information about how the participants of the Challenge Prize actually work together. This happened even though we tried to control this by finding evidence of learning processes in the Challenge Prize websites. In relation to working with sustainability, the interviewed Challenge Prizes were sustainability-oriented based on our judgment, but not all of them used the word sustainability or found it a concept that is useful for them. However, the interviewees were still able to give useful information in regards to other aspects that were interesting for our research.

Even with the different limitations mentioned above, the data we collected gave a rich and varied understanding of the subject matter, and it allowed us to see clear patterns in regards to the Challenge Prizes.

# 3  Results

## 3.1 Thematic Analysis

The thematic analysis helped us make sense of the data collected and also helped understand the qualitative, rich and deeply contextual nature of it (Daly, Kellehear and Gliksman 1997; Braun and Clarke 2006; Guest 2012). In the analysis, 13 themes were constructed during the coding process. For each theme, we analyzed the most prominent variables that emerged from the data gathered from the interviews with the learning experts. Then we analyzed how those variables were present in the Challenge Prize processes based on our perception of how they are actually present. The list of themes and respective variables can be seen in table 3.1.

| Theme | Variables |
|---|---|
| **Characteristics of the problem or the challenge** | Realistic challenge; Complex challenge; Specific challenge |
| **Methods of teaching** | Varied methods of teaching; Learning by doing |
| **Learning Process** | Presenting the challenge; Support for idea creation; Support for knowledge acquisition; Support for idea development; Support for reflection; Iterative process |
| **Feedback** | Feedback in general; Formative feedback; Peer feedback |
| **Core concepts of sustainability in a Challenge Prize** | Systems thinking; Implicit backcasting; Explaining complexity; Information about the sustainability challenge; Strategic planning tools; Clear definition of sustainability; Challenge addresses ecological sustainability; Challenge addresses social sustainability |
| **Assessing sustainability** | Sustainability appears in winning criteria; Tools are offered for sustainability assessment |
| **Experimentation** | Experimentation as a way to get comments and validate ideas; Experimentation as a way to virtually or physically prototype; Experimentation as a way to put theoretical knowledge into practice; Experimentation as a way to learn by mistakes |
| **Group work and collaboration** | Groups work is a requirement |
| **Group work environment** | Ground rules for group work are set; There is a safe space; Group work is structured; There is support to create trust in the groups |
| **Mentors and external experts** | Mentors; External Experts |
| **Learning in a competitive environment** | Structured learning process |
| **Diversity** | Diversity within the teams; Diversity in general |
| **Supporting the participants in finding information** | There is free accessible information for the participants |

*Table 3.1Themes and Variables*

This analysis was conducted to understand how learning is currently present in Challenge Prizes, and which aspects of it are lacking and should be improved to create processes that would enable better learning of SSD. In the end of each theme section, there is a summary that includes a scale from 0-10 that represents the presence of those variables for every Challenge Prize we interviewed. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present. Each Challenge Prize is abbreviated as follows: Nordic Built Challenge (NBC), Solar Challenge Brazil (SBC), Green Challenge (GC), Technovation (TV), Wege Prize (WP), XPrize (XP), SIA Austria (SA) and SIA Czech Republic (SC).

### 3.1.1 Characteristics of the problem or the challenge

This theme details what the characteristics of the problem/challenge should be in order to be most appropriate to a learning situation (e.g. Challenge Prize or other). A problem for a learner and a challenge for a Challenge Prize participant are considered to have a similar role.

*SSD experts*

When the SSD experts talked about the type of problems they use when they are teaching, they all mentioned the benefit of using problems that are real and that relate to the life of the learner. One SSD expert considered that the problem should be related to sustainability. Another expert also mentioned that the problem should be placed in the larger sustainability challenge and that the problem should be specific: "A lot of them [Challenge Prizes] have a very specific problem that they want to address...and then I think, you have to think about how you connect that to the bigger sustainability challenge" (Missimer 2015).

*PBL experts*

Two PBL experts emphasized the need of setting a challenge that is specific, tangible and real. For that, the challenge should be well defined in terms of performance criteria and the characteristics of the solutions. "...you need to get pretty specific. Not in terms of how to do it, but in terms of performance criteria for what this solution needs to [be]... so that's how I think it can become tangible and real" (Sims 2015).

*Challenge Prizes organizers*

When describing the challenges of their contests, the organizers mostly defined them in realistic and complex terms. One of the challenges, which related to building a solar powered boat, lacked complexity. Half of the challenges were not specific, since they talked about social impact and solving community problems. Eventually the participants would decide what the problem actually is, as described by the organizer of Technovation contest, in which they "...have a mobile app competition where girls determine a problem in their community that they would like to address and then they build a mobile app to address that community need" (Holmes 2015). Lastly, there was one Challenge Prize that did not present a challenge at all, therefore it was vague.

*Summary*

In this theme three variables emerged from the learning experts regarding the characteristics of the set challenge. These variables were that the problem/challenge should be realistic, specific, and complex. However, most Challenge Prizes proposed complex and realistic challenges, although in some cases they lacked in specificity, as seen in image 3.1. The far left

of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.



*Image 3.1 Variables in Characteristics of the problem or the challenge*

## 3.1.2 Methods of teaching

This theme refers to the type of methods of teaching that are used by the learning experts and whether those methods are used in the Challenge Prizes.

*SSD experts*

Three of the four interviewed experts stressed that it is important to use traditional teaching methods as lectures alongside more interactive methods. As Missimer (2015) said: "So I think people need to learn in the traditional way and then iterate it in a way that the learners play with it in different contexts, maybe that's a workshop". Two of those also mentioned that people have different learning styles and the methods should speak to those differences. They also mentioned that learning by doing is important and thought that it was very important for learning the SSD concepts.

Three experts mentioned concrete cases, real life stories and examples as an important way to convey how the theory looks in practice. And two of them mentioned games and playing as good methods to teach SSD concepts.

*PBL experts*

Regarding lecturing and traditional methods of learning, all PBL experts did see value in using them, for example in conveying certain initial knowledge or when teaching more theoretical concepts, but they did not think they were necessary in all situations. One expert said: "I have lectures as well. So that is not a I mean just because you have PBL it doesn't, you can still have lectures. They complement the learning. So I have a few in very different areas actually" (Jarl 2015). All PBL experts talked about learning by doing and found it to be important for deep learning.

*Challenge Prize organizers*

Three of the Challenge Prize organizers had a planned learning process for their Challenge Prize. Only one organizer clearly mentioned using different methods of teaching to engage the audience. Half of the interviewed Challenge Prize organizers mentioned that they used

workshops as a method. The workshops were either related to the topic of the challenge or offering some practical skills to the participants, for example presentation skills. Two explicitly mentioned lecturing as a method of conveying information. Technovation had built an online curriculum that the participants could follow, as mentioned by the organizer: "[talking about the curriculum]...then we walk them through building a business plan and a pitch video and sort of thinking through all the process like building the brand, how will they market their app, how will they raise money, how will they make money with their app, and sort of thinking the whole process of building a business" (Holmes 2015). Practical examples as a method for conveying information was mentioned by one organizer. One Challenge Prize organizer explicitly mentioned learning by doing when discussing teaching methods. However, learning by doing could be detected in all but one Challenge Prize.

*Summary*

In this theme two variables emerged from the learning experts regarding methods of teaching. They were that varied methods of teaching should be used in order to engage different learning styles and that learning by doing deepens learning. The Challenge Prizes did not describe a varied set of teaching methods and all but learning by doing could be detected in all but one process. Green Challenge was not considered in the scale for varied methods of teaching since it is nested in a university setting and it was not possible to analyze for that. In image 3.2 it is possible to see to what extent each Challenge Prize demonstrate these variables. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
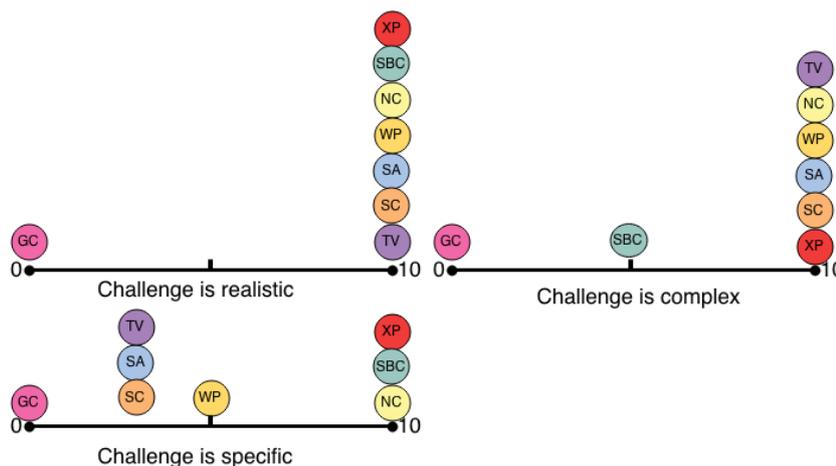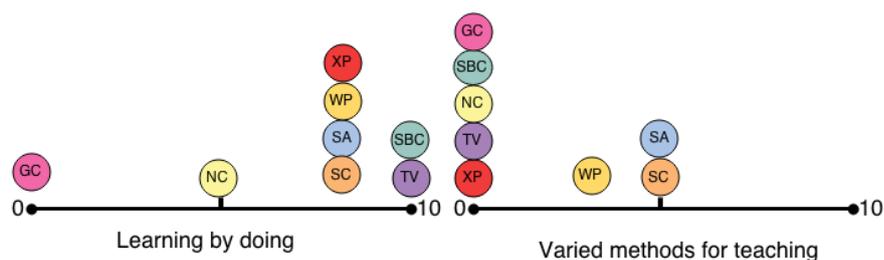


*Image 3.2Variables in Methods of teaching*

### 3.1.3 Learning process

This theme describes the characteristics of the learning process generally used by the learning experts, how they relate to PBL, and whether those characteristics could be detected in the Challenge Prizes.

*SSD experts*

When talking about the learning process in general, two interviewees expressed that it is important to start with a wider perspective and then go to details. Three interviewees mentioned that the learning process should have an iterative nature, where you learn something, do an assignment and then learn something new, and get feedback in between.

When it comes to stages of PBL, none of the interviewed SSD experts were applying it rigorously. Two of the interviewees acknowledged it being a philosophical approach to constructing the learning processes, with seeing the problem as central, and the two others perceived similarities with the stages of PBL when constructing their learning situations, but

have not been using it explicitly to plan the learning process. "If I used real PBL in a class, [I] feel there would be a lot more determined by the students to figure out what the problem actually is, before diving into the solution" (Missimer 2015).

When talking about the fifth stage of PBL, reflection, all SSD experts mentioned that reflection is very important for learning as it is a way for people to make the concepts their own and see what they do or do not understand: "I have a hard time to imagine learning without reflection" (Connell 2015). One of the interviewees mentioned that reflection allows for deeper learning in complex environments and that reflection practices should be provided in a safe environment. One interviewee said that it is good to build reflection opportunities throughout the process. Reflecting could be done individually or with a peer, it could be open ended or more targeted. The use of reflective questions to support reflection was mentioned as being supportive by one interviewee.

Regarding the development of ideas considering SSD concepts, two SSD experts mentioned some tools that could support the learner in idea development, such as physical models, animations and movies. Three SSD experts also had different views on the support SSD concepts provided to the creation of ideas. Two believed that using Sustainability Principles as constraints can be helpful on a general level: "…using the framework for its constraints to innovation can be helpful" (Connell 2015).

On the other hand, one expert believed that brainstorming within the constraints of the sustainability principles can be difficult. She suggested that ideas should be first developed freely and then analyzed with the lenses of the SSD: "You can't really think in constraints in that way, otherwise you are not, because we know that there aren't any sustainability solutions, because you will end up in a situation where you can't do anything" (Missimer 2015).

*PBL experts*

Regarding the application of PBL, the experts mentioned that time is an important variable since people need to adapt to working in groups and to the PBL teaching approach. People with experiences in those contexts adapt faster. As Nygren (2015) said "in a competition setting maybe there are students that actually apply to such competitions that are you know they are masters students that have been trained in many different ways and taught with many different learning approaches so maybe wouldn't be too much of a problem now".

PBL experts did not necessarily follow the stages of PBL in a rigid order. One of them mentioned that it is important to give the learners some kind of a foundation to start from, and another one stressed that structure is very important for successful learning situations, but following the stages was not important. One of the interviewees saw PBL as an inspiration for an iterative process that allows for reflection. The most important stage for one interviewee was the first stage, where the learners start with defining the problem with the help of the instructor, for another one it was the last stage, reflection. All PBL experts considered reflection important for learning. One expert mentioned how reflecting is especially necessary when it comes to sustainability, since sustainability requires new ways of thinking and reflection can help with that: "Maybe when it comes to sustainability this reflection part is also particularly important, because sustainability is very much about thinking in new ways, and in ways that we haven't lived or thought before, and it takes a lot of reflection to get there" (Nygren 2015).

One of the interviewees mentioned some tools that he uses to support the learners to create and develop ideas. Examples are design thinking, business model design, prototyping and lean

startup. Another interviewee mentioned brainstorming with pictures when starting with defining the problem.

*Challenge Prize organizers*

Challenge Prize organizers did not explicitly mention stages that would be similar to the PBL stages in their process or a learning process that would be especially iterative in nature. Though, as related to the first stage of PBL (Observation and information gathering), all but one Challenge Prize do present the challenge (problem) in some way to the participants, and four of them offer a way for the participants to gain further information about the problem. For the second stage (Questions, ideas and hypothesis formulation), it mostly relates to a process of creation of the ideas. Half of the organizers support the participants in this process by providing workshops, having sets of questions to help them to see the challenge in a different perspective or by providing them with mentors. For the third stage (Learning issues/Inquiry strategy), four of the Challenge Prizes had some kind of support for the participants to find information (external experts, workshops, written guides). For the fourth stage (Action plan), which is related to the actual development of the idea, half of the Challenge Prizes offer some kind of a support (a specific tool like business canvas, workshop, possibility to discuss with a stakeholder). The Challenge Prizes did not have intentional reflection times built in the process, except for one. This one had reflection questions in the curriculum provided to the participants.

One of the Challenge Prizes, who did not provide support in idea creation nor in idea development, did show intent to create a manual to support the participants. One Challenge Prize organizer mentioned that they did not have much knowledge on how the participants create or develop their ideas: "When we design the competition we set the goal like imagine that it is a sports game, like or it's a race and we are gonna set where the finish line is, how the team gets there is totally up to them" (Bravo 2015).

*Summary*

In this theme six variables emerged from the learning expert regarding the learning process. These variables were the five stages of PBL and the iterative process. Half of the Challenge Prizes had stages that were similar to four of the stages of PBL and none included reflection (Stage 5) as part of their process, henceforth there is no scale for that stage. Also, Challenge Prizes did not present an iterative learning process; therefore there is no scale for that variable. Image 3.3 represents these scales. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.

*Image 3.3Variables in Learning Process*

### 3.1.4 Feedback

This theme describes the importance and practices of feedback for learning, and how feedback is given in Challenge Prizes.

*SSD experts*

All SSD experts considered feedback as very important for learning, as it deepens the learning of the participants. Two experts thought that feedback given early in the learning process allows for deep learning, but they also talked about summative feedback which is given at the end of the process. "We try to build as much formative feedback so that their intermediate deliverables, they are deliverables that we give feedback that doesn't have a grade associate to it, because people pay more attention to it and that is more useful for people to get deeper learning from it" (Johnson 2015).

All believed that peer feedback is relevant for learning. However, two of them mentioned that there are challenges to this as the learners may be too nice or too mean when giving the feedback. Therefore, peer-to-peer feedback might be more effective if the feedback is guided by a rubric and when the feedback is not related to grading, as one of the interviewees said "...a rubric to say this is what it looks like if it is very good and this is how it looks like when it is good. So then the peers have guidance on what is expected versus I can focus on any random thing" (Missimer 2015).

*PBL experts*

Only one PBL expert talked about feedback. The expert thought that feedback should be given in two different ways, during the process or after the process. The feedback during the process is used as guidance while feedback after the process is a way to inspire the students to become independent.

*Challenge Prize organizers*

Six of the Challenge Prizes incorporated summative feedback in their process. In five Challenge Prizes there is no specific phase or a formal process for feedback; instead there is an opportunity for receiving optional feedback in workshops or from stakeholders of the process. In two Challenge Prizes all teams receive some kind of feedback from the jury or from the organizers, and that feedback could be seen as formative, as one interviewee explained: "We did provide individual feedback from the judges to each of the teams. So the teams that did not get to the finals, they got some feedback from the judges as well on how to make it better" (Tislerics 2015). One Challenge Prize did not see feedback as a relevant practice for a competition: "There isn't a formal feedback process because this is actually a competition and they are trying to win so we don't tell them how to make their ideas better" (Bravo 2015).

*Summary*

In this theme three variables emerged from the learning experts: summative feedback, formative feedback and peer feedback. Most of the Challenge Prizes had summative feedback, but not all of them provided formative feedback and only one provided peer feedback. There was also an opposite view that feedback should not be provided since Challenge Prize is a competition. These scales are represented in image 3.4. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
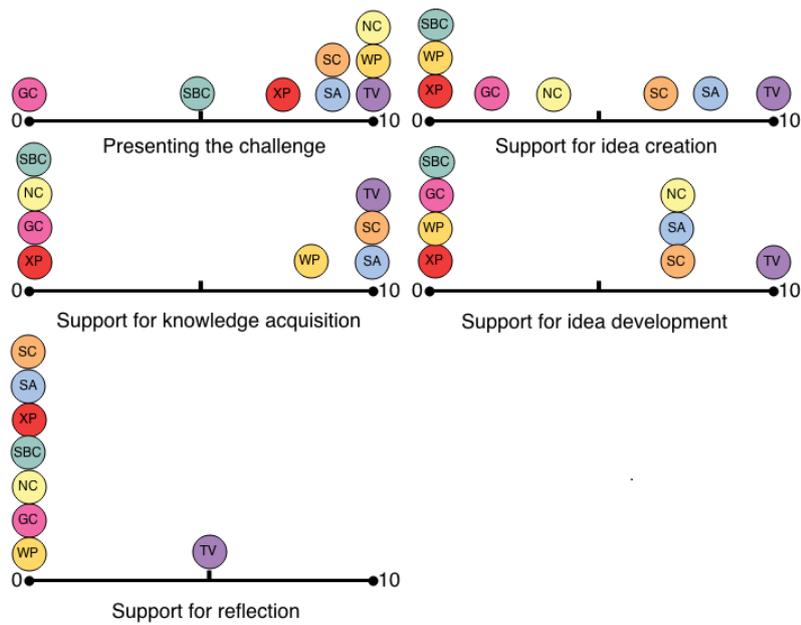


*Image 3.4Variables in Feedback*

## 3.1.5 Learning in a competitive situation

This theme describes how the learning experts saw learning in a competitive situation and how they would envision a contest with SSD content (for SSD experts) and a PBL approach (for PBL experts). It also shows how learning is currently present in Challenge Prizes on a general level.

*SSD experts*

One SSD expert was concerned that a competitive situation would foster superficial learning, since the participants would try to come up with solutions fast. This danger was considered to be higher if the prize is of high monetary value. If the prize is related to education, as an incubator period for example, the participants could be more motivated and engaged to learn

during the process. Other two could not think of specifically negative or positive consequences of learning in a competitive environment, but one had the opinion that maybe introducing the SSD concepts to the Challenge Prize would make meeting the challenge more complicated. As Missimer (2015) said "I can't think so much impact of the challenge on SSD learning. Maybe it is the other way around; maybe the SSD part makes the challenge part more complicated". Three of them thought about time constraints, and two saw that there was a possibility to engage people who like to compete.

*PBL experts*

Only two PBL experts had an opinion about learning in a competitive situation. They both mentioned that setting a structure for the learning process of a Challenge Prize contest would be very important. As for other aspects, one saw as helpful if the Challenge Prize organizers understood learning theories better and believed that if learning is the main aim of the Challenge Prize, it would probably mean that the solutions may not be exactly as expected. And the other stressed the importance of the process in terms of group work and how the participants should be made to think by themselves. He also saw a possibility for thinking about the participants as the final product, instead of only seeing the final solutions as significant outcomes. As he said: "And you have to...I mean you might not get what you think you will get or what you expect to get back. But that maybe you can still see that they learn something and that is the thing" (Jarl 2015).

*Challenge Prize organizers*

Challenge Prize organizers did not see any specific negative consequences related to learning in a competitive environment. On the contrary, half of the Challenge Prize organizers expressed that their contest had as one of their purposes that the participants would learn something. As related to the learning structures, three of the Challenge Prizes had a structured curriculum.

Five Challenge Prizes also stressed that Challenge Prizes can have an effect of attracting people to learning about different topics for example science, technology and innovation. As Bravo (2015) said: "I personally think that getting the public interested, getting kids interested in science, getting girls interested in science and technology like all of these things are things that prizes are very good at". Two also saw that Challenge Prizes can raise awareness on certain topics.

*Summary*

In this theme one variable emerged from the learning experts: a competitive situation which aims at learning would benefit from a structured learning process. This variable appears in the scale in image 3.5. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
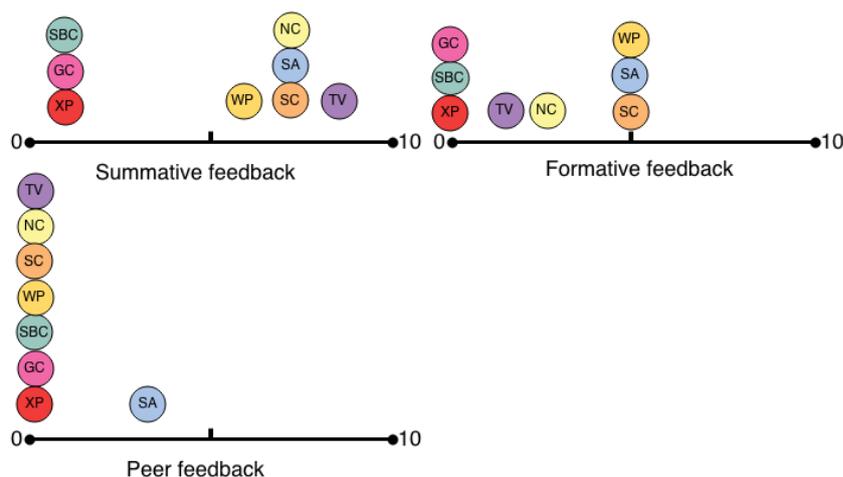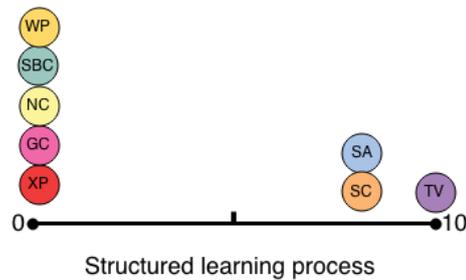
*Image 3.5Variable in Learning in a Competitive Situation*

### 3.1.6 Core concepts of sustainability in a Challenge Prize

This theme mentions what would be identified as the most important SSD concepts for people to learn SSD and start applying them. Additionally, it was analyzed how some of those concepts are currently present in the Challenge Prizes.

*SSD experts*

Systems thinking, Sustainability Principles, backcasting and complexity were mentioned as core concepts of SSD by two interviewed experts: "...taking a holistic systems perspective, will mean that you will solve a problem without creating another" (Johnson 2015). Another two mentioned the Five Level Framework. And one interviewee mentioned the ABCD process, the FSSD and explaining the Sustainability Challenge through the funnel metaphor as an important aspect.

The order that one interviewee would start teaching the SSD concepts is first the Sustainability Principles, then backcasting and explaining complexity and lastly practical examples, another SSD expert would start with the systems perspective and complexity of the challenge, and then explain the Five Level Framework. That interviewee also thought it was important to teach all SSD concepts, since otherwise they are hard to understand: "...and I don't think you can take one concept out of context, they need to come with the full package otherwise you don't get the full picture" (Missimer 2015).

Regarding the core concepts all SSD experts mentioned that the prior knowledge of the participants affect how fast they can learn the concepts, for example engineers understand SSD concepts faster: "Engineers get the framework really quickly, persons coming from a background in performing arts, they [are] probably not going to get it so quickly" (Connell 2015). One of them also brought up the idea that the level of detail you need the participants to learn will affect how much time you spend on explaining the concepts.

*Challenge Prize organizers*

In general, the Challenge Prize organizers did not offer a systems perspective for their participants. Four of them offer some tools or other methods, for example business canvases, that encourage the participants to understand and analyze a local subsystem where their solution will operate. One of the Challenge Prizes offered a more holistic view of the socio-ecological system through The Nordic Built Charter that was specially designed for the topic of the Challenge Prize. And another Challenge Prize offered a partial systems perspective by having the participants consider whether their solution would have a negative impact: "We try to coach the teams [so] that they don't create another issue by creating the solution" (Bojko 2015).

Regarding the Sustainability Principles, since the Challenge Prizes are competitions, they all had a definition of success for the challenge that appeared in the form of winning criteria. Since none of the interviewed Challenge Prizes were familiar with SSD, their definition of success was not based on the Sustainability Principles. However, they all could be seen to work with either ecological or social sustainability. One of the Challenge Prize organizers described a definition of success that was based on a charter with principles. Only one Challenge out of the interviewed challenges had a clear definition of sustainability, as explained by the interviewee: "...in general we used the Brundtland definition, sort of the three pillars of sustainability and that has been clarified or elaborated in the 10 principles of the Nordic Built Charter that are sort of specific for buildings" (Fridberg 2015).

Most of the Challenge Prizes allowed for an implicit backcasting from a vision of success, which constituted of the communicated winning criteria. One Challenge Prize did not communicate the winning criteria to the participants; however, the organizer noticed a need for communicating it: "Something we have learned this year is that we should consider publishing the rubric" (Tislerics 2015). The term backcasting was not used by the organizers.

This Challenge Prize was also the only one that referred to an activity that could be a way to explain the sustainability challenge to the participants, by providing information about wicked problems: "The information that we provide them is largely on wicked problems and circular economy and things related to that" (Tislerics 2015). None of the Challenge Prizes explained complexity-related concepts to their participants. Three Challenge Prizes offered strategic planning tools for their participants that had a similar purpose as the tools mentioned by the SSD experts (ABCD, 5LF).

*Summary*

In this theme eight variables emerged from the learning experts: these variables were the most important concepts of SSD. These are the Sustainability Challenge, Clear definition of sustainability, Systems thinking, Backcasting, Complexity, Strategic planning tools, Challenge addresses social sustainability and Challenge addresses ecological sustainability. Some Challenge Prizes offered a partial systems thinking for participants, an implicit possibility for backcasting, and some strategic tools and mostly no information about the Sustainability Challenge or Complexity. All interviewed Challenge Prizes address social or ecological sustainability to a certain extent. These variables are shown in image 3.6. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.

*Image 3.6Variables in Core concepts of sustainability in a Challenge Prize*

## 3.1.7 Assessing Sustainability

This theme mentions different forms of assessing sustainability.

*SSD experts*

Two interviewees mentioned that an analysis of impact on the Sustainability Principles could be conducted. They also deemed important that the participants could analyze how their solution contributes towards solving the larger sustainability challenge: "...[the participants should] position [their solutions] in the larger sustainability challenge and [then] they justify why it is a better option or solution" (Missimer 2015), and how they would analyze the unexpected impacts.

Other two interviewees suggested using specific tools for evaluating if the ideas are in alignment with the SSD, examples were the MSPD method and the Sustainability Life Cycle Assessment based on the principles tool: "The [sustainability] life cycle assessment is pretty good, it is probably the most comprehensive in line with the framework [for Strategic Sustainable Development], if it is a product. So that is probably the best way to test that"

(Connell 2015). One of these interviewees together with another also mentioned that the participants should think about the long-term consequences of the solutions.

When visioning how a Challenge Prize contest with SSD would look like, one suggested including the Sustainability Principles to the winning criteria, so that the participants could backcast from there. Another interviewee stressed that in addition to Sustainability Principles, a performance criteria, like an evaluation standard, would be important for assessment. A second interviewee also discussed the concept of leverage points for assessing sustainability, i.e. on which leverage point the solution would be able to influence.

*Challenge Prize organizers*

Assessment in the Challenge Prizes happened through the winning criteria. Sustainability was mentioned in two of the criteria, for example, in the Nordic Built Charter: "[Sustainability] has been clarified or elaborated in the 10 principles of the Nordic Built Charter that are sort of specific for buildings" (Fridberg 2015). Two Challenge Prizes offered a tool, as the Life Cycle Assessment and BREEAM certification, to help the participants in assessing the sustainability of their solutions. Only two other Challenge Prizes had winning criteria that was defined as clearly measurable and definite, as the rest of the winning criteria were more subjective, measuring aspects as innovativeness or how realistic the solution is.

*Summary*

In this theme two variables emerged from the learning experts: Sustainability should be included in the winning criteria, and tools can be offered to support sustainability assessment. Most of the Challenge Prizes interviewed did not have these variables. A scale with each variable can be seen in image 3.7. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
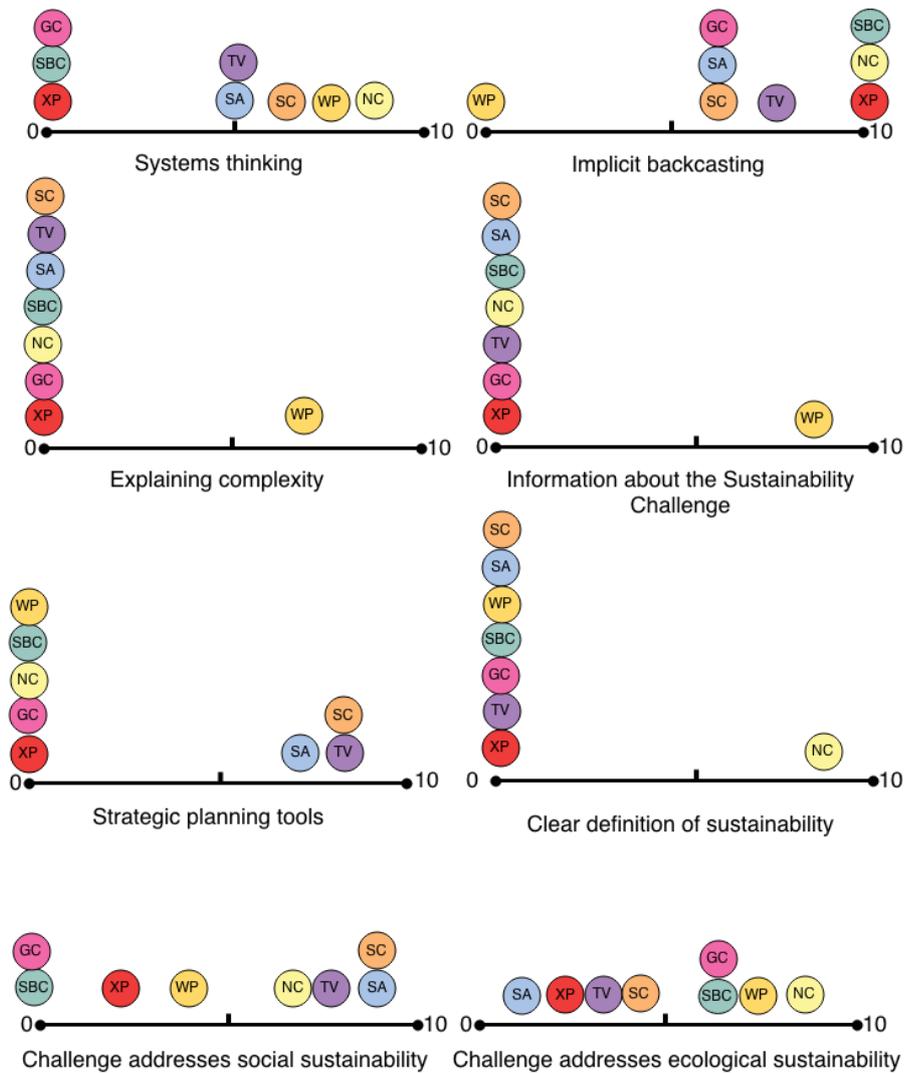


*Image 3.7Variables in Assessing Sustainability*

## 3.1.8 Experimentation

This theme describes how learning experts see experimenting, defined as trying out or testing the idea developed.

*SSD experts*

Two of the SSD experts saw experimentation more as an intellectual practice than actually creating physical models or prototypes. They saw experimenting as a process where an idea is presented to others and critiqued, and this could be done for example by creating representations of reality with Lego. The other two experts considered experimenting as either virtual or physical prototyping, or thought that it was useful and important. One interviewee

perceived a lot of benefits in experimenting virtually. The other one connected experimenting to being able to learn from one's mistakes and being able to get feedback in the early stage of a process. That interviewee also talked about rapid prototyping as a good way of developing ideas and getting comment from users: "We encourage them to do really crude and simplistic way of modeling for creating a prototype to whatever solution...Then they can interact with people and get [comments]" (Johnson 2015). Three of them stressed that it is important to put the theoretical knowledge into practice and that can be achieved through experimenting.

*PBL experts*

The PBL experts saw experimentation as a way to learn, but two of them did not include it in their learning process. One interviewee said that during experimentation it is possible to learn by doing and another one said that they do a lot of it, but not very formally. However, one interviewee saw experimentation as a way to receive comments and validate ideas, and when communicating ideas through a prototype to others, the designer will understand his/her idea better: "There we do experimenting, a lot of what we are doing is not so formal, like I believe x, so I'm going to test hypothesis x, it is more like trying things out... it is also like a sense making process for articulation or communicating an idea to yourself and to others, so that you can sort of edit it" (Sims 2015).

*Challenge Prize organizers*

None of the Challenge Prizes interviewed have an actual experimentation phase. However, two of them offer a physical space for experimentation. It is important to note that even though in the cases that no space was offered, four of them said that it can be very important for the participants to experiment on their ideas because it is an opportunity for them to receive comments and validate their ideas. Therefore, depending on the challenge it can be even more important to prototype and receive customers' opinions to evaluate the potential success of the product. One interviewee said that the experimentation can be a simple demonstration of what the final product would look like. One of the Challenge Prizes gave a tool for creating web applications to its participants to develop their solutions and with that tool the participants were able to check if their solution was functioning properly. Another one used the day of the competition to experiment on what the participants had created and see whether it worked or not.

*Summary*

From the learning experts four variables emerged related to experimentation: as a way to put theoretical knowledge into practice, as a way to virtually or physically prototype, as a way to learn by mistakes, and as a way to validate ideas. However, experimentation as a way to put theoretical knowledge into practice and as a way to learn by mistakes did not appear in any Challenge Prizes, therefore there are no scales for those variables.

Challenge Prizes did not include a specific phase for experimentation, but they thought it had value. Two Challenge Prizes encouraged for experimentation in order to get user comments and one provided a tool that allowed for experimentation.

Regarding the variable experimentation as a way to virtually or physically prototype, SIA Austria and SIA Czech Republic do not appear in the scale since their solution is not considered appropriate for prototyping because they create a social enterprise and not a product per se. These scales can be seen in image 3.8. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
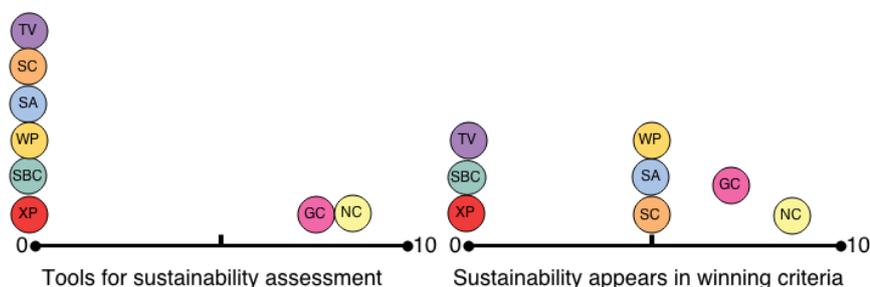
*Image 3.8Variables in Experimentation*

### 3.1.9 Group work and Collaboration

This theme mentions the importance of group work for learning and how group work and collaboration are present in Challenge Prizes.

*SSD experts*

For all SSD experts, group work is a relevant aspect when learning SSD. Two interviewees believed that working in groups contribute to deep learning since people learn when they need to teach others and give examples. As Missimer (2015) said "...I think group work is important for learning any concept because...it allows you to see different perspective and have a conversation and test your understanding in others". One expert reiterated the fact that in groups of people can learn from each other, as people are social beings and therefore learn best in a social environment.

*PBL experts*

One PBL expert reiterated that learning how to work in groups is essential for PBL, since it always takes place in a group environment. This approach also trains the learners in group work skills: "...benefits of doing that [working in groups] is that it actually practices you as you get the same type of knowledge as you do from other didactics but you also learn and train yourself in team work" (Jarl 2015).

*Challenge Prizes organizers*

All the Challenge Prizes organizers consider that group work is important, except from one interviewee that could not affirm that there is a difference of performance between groups and individuals. Two of the organizers affirmed that teams are more successful: "Personally, I feel like things are better when you are working as part of a team. I don't think we have any individual student make it to the world pitch event, so I would say that if we are using that as a reference point then it is probably better to work as a team" (Holmes 2015).

Other aspects were also pointed out: one of the interviewees said that you need to work in groups to deal with wicked problems, which is their challenge topic, another one consider that groups need to be cohesive in order to succeed in the development of the idea and its business plan. Another two organizers commented that they have a mix of groups formed by people that knew each other before the contest and by people that did not. They did not notice a difference in performance related to this aspect.

On another level, the Challenge Prize organizers also acknowledged the importance of collaboration among the teams. Collaboration between participants was mentioned as a valuable aspect by four interviewees. Two of them believe that people collaborate when they know about what other participants need. Other two considered that the teams can learn from

each other and although they do not provide a space for this, they want to improve that by using an online platform or by promoting matchmaking events. One of these mentioned that it was good to have an open process: "They were trying to basically not share too much, which is also a design flaw from our side I would say, because actually the good things comes out of [an] open processes" (Fridberg 2015). In at least one Challenge Prize, the participants also had an opportunity to pitch their own ideas in a workshop and offer support for each other. Another two interviewees said that they recognize the need to improve this aspect and they are developing better online platforms for this to happen.

Lastly, two of the Challenge Prize organizers expressed a contradiction between the need for collaboration and between the fact that the teams were competing for a prize, and therefore would not be willing to share ideas or challenges they were encountering.

*Summary*

In this theme, one variable emerged: group work is important for learning. All Challenge Prizes accepted teams and most Challenge Prize organizers emphasized the fact that groups are more successful in competitions than individuals. This can be seen in image 3.9. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
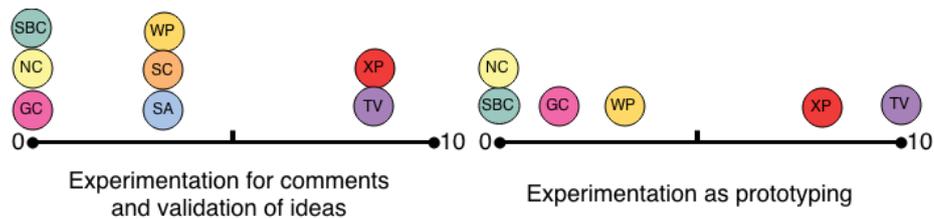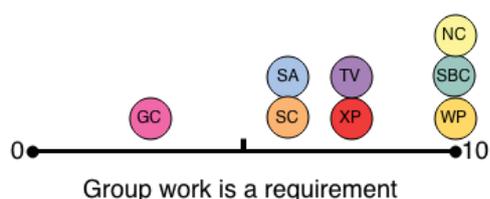


*Image 3.9Variable in Group work and collaboration*

### 3.1.10          Group Work Environment

This theme mentions what aspects are important for creating an environment that supports group work for learning, and how group work is supported in the Challenge Prizes.

*SSD experts*

When talking about good conditions for group work, one of the experts had a strong view that three is the perfect number of members in a group. The others did not have a specific point of view on that. Regarding good conditions for group work, one practitioner emphasized the need for listening, openness and no judgment: "I think there is a lot of listening, openness and no judgment and those kind of things and kind of exploring together" (Missimer 2015). Other two interviewees said that setting expectations and ground rules in the beginning is helpful. They considered that this helped to build a safe and positive space, allowing the learner to be more comfortable to make mistakes and ask questions. Finally, two interviewees said that it is important to provide some structure for the group work.

One of the interviewees discussed how the interaction in person versus online is important for learning. He mentioned that there are many online tools to help with group work, but that it is hard to reach the same high quality of having people interact in person. It is noticeable that the interaction improves if people meet at least once and then keep working in distance.

*PBL experts*

For two PBL experts, working in groups creates the challenge of social dynamics. Learning can be hindered if the group members do not get along. All of the experts mentioned that it is important that the instructor builds the structure for the group to work. This involves planning the meetings, setting a timeline, establishing ground rules and clarifying assumptions.

One expert mentioned that when time is provided for the group work, it is possible for the instructor to let go and let the conversation run freely; however, when there is a limit amount of time the instructors should structure and guide the group work more, as well as define the problem they are working on: "…if you have lot of time you can sit back and listen to them talk and then they discuss and hopefully they arrive at the goal in the end but if the time is limited then maybe sort of guide them harder against the curriculum so you don't let them speak as much or work as much" (Jarl 2015).

Creating trust and building relationship in the group is very important according to one of the interviewees: "So it has to be a high level of trust in the group, you trust each other to do the work, you trust each other to not just do the work but to do the work in a proper way... you have a responsibilities to the others I think, so trust and also realize that each and every person in the group must do the work is valuable otherwise there will be no end result" (Nygren 2015).

When talking about the size of the groups, they had diverse opinions, one of them said that the ideal number is 5 people, while another said that it should be in between 7 and 9, the third interviewee did not have a specific number.

One of the experts also mentioned that it is valuable to leave space for informal interaction by promoting social networking, celebration and creating a collective culture. He also considers that this helps to create an inspiring competition, when talking about Challenge Prizes.

*Challenge Prizes organizers*

The teams are formed after the challenge is set but before the process starts and in five cases there was a workshop or an online platform that can be used to find teammates. The size of the groups varied. In general, the interviewees did not have a clear idea of how the groups work when they are on their own. One of them mentioned that having an effective team structure seems to be key to success, and another mentioned that having online tools for interaction between the group members is a common practice, but not instigated by the organizer. None of the Challenge Prizes provided support related to group work practices or methods.

*Summary*

From the learning experts four variables emerged regarding group work environment: it is important to set ground rules, it is important to create safe space, it is important for the group work to be structured and it is important to create trust in the groups. The Challenge Prizes had little information about how the groups work together and did not offer any support for group work processes. No scale was produced for these variables since no clear information was apparent in the data regarding them.

### 3.1.11 Mentors and external experts

This theme mentions the significance and role of a mentor and an external expert for a learning process. It also mentions how Challenge Prizes currently employ these forms of support for their participants.

*SSD experts*

All four SSD experts considered that a mentor who guides the learner through the process is more helpful than an expert offering knowledge. The mentor's role is more about providing structure for the process and asking good questions that will allow the learner to find a solution autonomously, as explained by an interviewee: "I think a mentor is much more helpful because, by definition the role is different and the whole point of the mentor, advisor, coach or whatever is to help the group or the individual to get somewhere that they want to get" (Missimer 2015).

On the other hand, the SSD experts agreed that the help from an expert is necessary when dealing with specialized content and that would help in the development of the solutions. However, this might not be ideal for learning, since external experts tend to show the answers to the learners. One of the interviewees said that since the SSD concepts are hard to understand in detail, there is a need for an expert to teach them: "...often the SSD concepts I think...if you want to manage to understand those concepts it requires an expert to teach them in some way. I think it is such a specialized way of thinking, so it is hard to say that: here it's a problem, go figure out, and assume that someone will come out with something similar" (Missimer 2015). Another expert mentioned the need of someone to connect theory and reality, which was mentioned as an expert's role by another interviewee.

*PBL experts*

All PBL experts pointed out that in PBL the instructor has a role that would resemble more a mentor. This means they guide the learners and are careful to give enough space for the learners to find their own solutions and make their own mistakes. The mentor helps the group in the group work process and provides the necessary structure for the learning process. For one interviewee, the mentor can also give content related advice, e.g. recommend readings. Another one stressed that the mentor needs to be very aware of their role and leave enough autonomy to the students: "I have to sort of restraint myself and hold back sometimes that I maybe want to tell them. 'Well you know if you think like this or if you do like this is going to solve a lot of problems for you'" (Jarl 2015).

*Challenge Prize organizers*

Two Challenge Prizes had a mentoring practice. In general, the teams were responsible for finding mentors on their own, one Challenge Prize offered a contact database for that. Two interviewees mentioned that it is important that the mentors already have some experience on a similar process. "With mentoring, the ideal is to have a number of people who have an overview and who have already experienced the stages the people have been going through" (Bojko 2015). In one Challenge Prize that works with young girls the mentors had a crucial role in supporting the girls since there was otherwise no organized workshops. In this Challenge Prize the organizers had noticed that the teams with effective mentors were most likely to succeed.

Regarding external experts, Challenge Prizes have different approaches. For one of the organizers, although they do not offer any expert support, the participants have access to the

teachers at the university in which the Challenge Prize is nested. For another Challenge Prize organizer, he said that they did not consider offering this since they expect that the participants already have the necessary expertise to solve the challenge. However, he did think that it would be helpful to have support from sustainability experts. A third organizer said that some of the mentors do have a technical expertise and they could help the participants with that, however she was also indecisive if this is good, since for her, a lot of programming, the focus of her Challenge Prize, is about figuring out by yourself. Two other organizers believed that the teams do have external experts supporting them, but they do not have information about it since it is up to the teams to decide. Lastly, there is one Challenge Prize that only offers support from experts to the finalists. The Challenge Prize organizers did not see as a problem that the external experts might provide the answers to the participants.

During the interviews, it was discovered that many experts serve as mentors for the groups or vice-versa as the mentors provided by the organizers tend to be knowledgeable on the challenge topic.

*Summary*

There are two variables in this theme: mentors are important for group work process and external experts can help with specific content. Challenge Prizes organizers have different approaches to mentors, but it was mentioned that having a mentor to guide the teams in the process is beneficial. In regards to external experts, they realize their benefit for content specific topics. These can be seen in image 3.10. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.



*Image 3.10Variables in Mentors and experts*

## 3.1.12          Diversity

This theme discusses diversity in a learning situation, and how diversity currently appears in the Challenge Prizes.

*SSD experts*

All SSD experts agree that diversity is important when working in groups. Diversity in the group was seen as a positive aspect that enhances creativity and innovation by one interviewee: "Diversity is generally acknowledged as an important factor for creativity and innovative work" (Broman 2015).  Another one mentioned that it also opens people's minds and brings new perspectives. For a third interviewee, it is important to know how to deal with diversity as an asset instead of an obstacle, and for that purpose it is good to create an environment that is favorable to listening, non-judgmental and open.

*PBL experts*

All PBL experts agreed that diversity is an asset. Two of the experts pointed out that diversity in gender, age and background is very good for learning. For one interviewee, diversity brings new and different perspectives to the problem. Another one affirmed that different people will play different roles in the group. For a third interviewee, diversity is beneficial since the people can learn from each other: "I mean you want different approaches, you want different perspectives on the problem. Because that is what created the group or that's how they learn from each other" (Jarl 2015).

*Challenge Prizes organizers*

When asked about the relevance of diversity in the Challenge Prizes, the organizers recognized the importance of it. They talked about it regarding two levels: within the group and between all the participants. Having diversity between all the participants does not necessarily mean that the teams are diverse as some Challenge Prizes are international but the teams are composed of participants from the same region.

Regarding the diversity within the groups, it is a consensus that it is important. Three interviewees emphasized that diversity in the group contributes to the development of new solutions in new and more innovative ways: "...architects tend to come up with very specific type of solutions, but here they had to work with for example some engineers or sociologists or whoever they brought into the team, and it really gave some different solutions than what these owners of the buildings were used to seeing" (Fridberg 2015). Two organizers consider this is essential and they require the groups to be diverse in the application. One of them requires participants from different educational backgrounds and the other asks questions that require a transdisciplinary approach to answer them. Three of them said that diversity is important, although they have a specific target group (e.g. just undergraduates of certain schools), reducing the diversity potential: "Diversity, it's limited, because it's a student program, so it is all students, this comes back from when the program started at the university" (Heatherman 2015). Finally, one organizer said that, considering that the target group is of engineers, they had difficulties in interacting with other types of participants.

Regarding diversity in general, two of the interviewees saw that operating internationally or regionally made the Challenge Prize diverse.

*Summary*

Diversity is a variable that emerged from the learning experts and it appears in the Challenge Prizes in two levels, within the teams and in general. For Challenge Prizes organizers, diversity within the groups is a benefit and some of them requested the teams to be diverse. They also mentioned the diversity regarding all participants and they realized that can be limited by the definition of a target group. Two of them tackle this aspect by working internationally. These two variables are represented in image 3.11. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
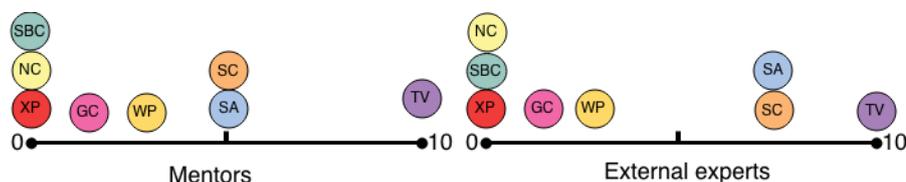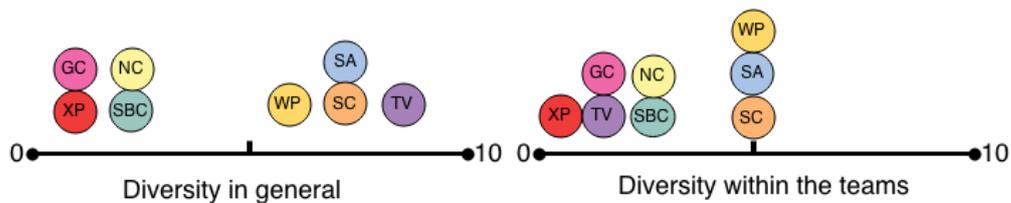
*Image 3.11Variables in Diversity*

## 3.1.13         Supporting Information Finding

This theme mentions the significance of supporting the learners to find information and how the Challenge Prizes currently do it.

*SSD experts*

Only one SSD expert mentioned the importance of having accessible materials for the learners for further information, but reading materials and videos were recommended to use as support to learning by two experts.

"These [materials] should be free and easy for the participants to find by themselves" (Connell 2015).

*PBL experts*

Only one PBL expert mentioned that if the problem requires understanding of a particular topic, the teacher can support the participants by providing this knowledge. Regarding the sustainability aspect, the interviewee said that it could be beneficial to present the participants with the foundations of sustainability before defining the problem, so that they can examine the concepts that they need to solve the challenge.

*Challenge Prizes organizers*

For seven Challenge Prizes organizers, it is important to provide information about topics related to the challenge. Only one organizer said that they do not support the participants with further information that might be relevant to the solution. For the others, five provided information related to the challenge on their website, as materials about relevant topics, and they also had a questions and answers section online. Three of them also provided information on workshops or visits to places relevant to the challenge. "We provide them the big picture, but I think they need to go into more detail individually" (Tislerics 2015).

One issue that arose was the fact that if the contest is international, more effort is needed in translating materials and if there are workshops, the language the workshops are held in may restrict participation.

*Summary*

One variable emerged from the learning experts regarding providing information: the learners should have free accessible information. Challenge Prize organizers recognize the importance of providing the participants with relevant information about the challenge and they do that in different forms. Two Challenge Prizes do not provide any support. In image 3.12 it is possible

to see this variable in a scale. The far left of the scale (0) represents the variable was not present in the Challenge Prize and the far right (10) represents that it was fully present.
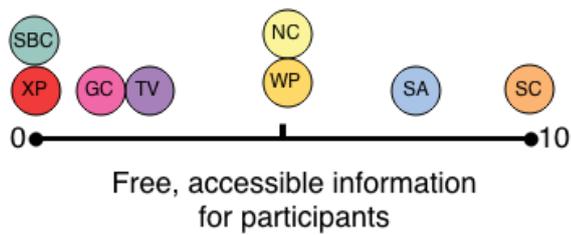


*Image 3.12Variable in Supporting the participants in finding information*

# 4  Discussion

In this thesis we researched how SSD concepts are taught, how the PBL approach is used in practice and how learning is present in Challenge Prizes. We looked at how learning currently happens in Challenge Prizes and how their processes could be further improved with the help of PBL, in order to include learning about SSD.

We identified different conditions, methods and areas that facilitate learning and observed how those are present or lacking in the interviewed Challenge Prizes.

## 4.1 How do Challenge Prizes facilitate learning?

The process of a Challenge Prize is just one part of the whole design of a Challenge Prize, and is therefore influenced by factors that are not taking place in the actual process. As stated in the introduction, the process of a Challenge Prize takes place between the launch of the challenge and the awarding of the prize. Even though events before the launch of the contest and after awarding the prize were not studied in this research, we acknowledge that some of their aspects affect the process. For example, in this research the nature of the prize to be awarded appeared as a factor relating to the participants' motivation to learn and could be further studied. Setting the challenge and creating the winning criteria also happens before the actual process but was found to have a high influence on the participants' learning.

Although we acknowledge all of the above, our data was focused on the actual process. When analyzing the data, we noticed some patterns in relation to learning in the specific cases that were interviewed.

About half of the Challenge Prizes that were interviewed had learning as one of their goals. However, only some of these offered support for the learning process of the participants. The Challenge Prize that offered most support for participants in regards to learning was Technovation, which also had a strong focus on learning for the participants, instead of focusing only on competition. Also SIA Austria and SIA Czech Republic saw learning as one of their goals and supported that. On the other hand, Nordic Built Challenge and Green Challenge did not support their participants in relation to learning, even if they stated it as their goal. The reason for not supporting the participants in these contests was related to assumed expertise of the participants and to the fact that it was assumed the participants would get enough support from elsewhere.

The interviewed Challenge Prizes that most emphasized the competitive nature of the prizes (e.g. XPrize) also offered least support for the participants for their learning process. They also justified this by explaining that they are all about competition and the teams need to come up with the solutions without support.

Some Challenge Prizes had incorporated learning opportunities for the participants so that they could create better solutions (e.g. by offering challenge related information or supporting the development of practical skills), even if they did not state learning as their overall goal. The participants learned by doing while working on their solutions. As stated in learning theories, applying theoretical knowledge to practice increases the understanding of the learner, making his/her knowledge more applicable and accessible. Though, if the organizers focus mainly on the quality of the solutions it may mean that the contest may favor people who have significant prior expertise on the specific challenge and perhaps already bring an idea that can be

developed into a solution. On the other hand, if learning is the main purpose of the Challenge Prize, it is accessible to more people but the solutions might be of lower quality.

In this research we identified several practices in Challenge Prizes that facilitate learning. Some of the practices are an innate part of every Challenge Prize process while others are added in the design by some organizers in order to foster learning in the participants.

Innate areas of every Challenge Prize process that foster learning are group work, collaboration, bringing together diverse groups of stakeholders, creating and developing an idea and learning by assessing a solution. All the interviewed Challenge Prizes provided opportunities for group work, which allows the participants to learn teamwork skills and can help in creating more innovative ideas. They also offer spaces for collaboration and therefore foster social learning. Additionally, they also commonly bring people from diverse backgrounds together, offering possibilities to learn by obtaining different perspectives through interaction among the participants. Moreover, creativity and design skills can be learned through the creation and development of the solution and assessing the solutions against the winning criteria, which was commonly communicated to the participants. Many of the interviewed Challenge Prizes also offer feedback to their participants, when they submit their ideas, which allow the participants to better understand how their ideas could be further developed.

In addition to these learning aspects that are shared by all Challenge Prizes, some organizers offer opportunities to learn through providing information and expertise that is related to their challenge, for example, by providing workshops, external expert assistance, lectures and reading materials.

It would be helpful for the organizers to be aware of PBL and other learning theories, in order to better incorporate learning through areas identified in this research. It was clear for the researchers that the Challenge Prizes could benefit from recommendations in order to better support learning. Specific opportunities for improvement included supporting group work in different ways, creating the learning process in a structured and iterative way, using varied methods of teaching, providing reflection opportunities, supporting idea creation and development and supporting diversity and collaboration among participants in a more effective manner.

## 4.2 In what ways could the learning process of sustainability-oriented Challenge Prizes be improved by a rigorous application of Problem-based Learning?

In this research we looked at Challenge Prizes as a concept that naturally relies on Problem-based Learning, since they are centered on real-life problems that participants are trying to solve.

During the interviews, the learning experts stated PBL appears to be used as a philosophical approach when designing learning experiences and that its different stages are not followed rigorously. The application of PBL usually happens with the design of a learning experience based on the core aspects of PBL, such as group work, collaboration, the search for a solution to a complex problem and having a tutor to guide the group process.

The gaps and opportunities for improvement related to PBL that became apparent in the research are related to the support that the organizers can offer to the participants in their group processes and in the development of the solution.

## 4.2.1 Application of PBL in the context of a Challenge Prize

When Challenge Prizes intend to create a learning process for their participants, they could benefit from being aware of the PBL approach and by adapting it to their context.

The Challenge Prizes already rely on aspects similar to PBL as there is clear intention to solve a problem via group work. Furthermore, some of the Challenge Prizes have a process with stages that resemble some stages of PBL.

*Guiding the Learning Process*

Both from the PBL literature as well as from the interview with the experts, we noticed that in PBL the learning experience is led by a tutor that has a different role than a teacher traditionally has. The tutor provides the structure to the process, guiding the learners and helping them to follow the process. Some Challenge Prizes already seem to be familiar with the role of mentors to support the participants during the process; who have a similar role as tutor in PBL. However, they could be oriented in order to better do their job if the organizers would be aware of PBL and the role a tutor has in the theory. The interviewees also discussed the difference between a mentor who guides the process by for example asking questions, and an expert who provides knowledge and expertise. The role of mentor was seen more useful for the learning experience. In the Challenge Prizes the same people often play both roles. Lectures or other complementary forms of training to participants could be conducted by external experts. This would allow Challenge Prizes to rely on external collaborators to support both the process as well as specific content, eliminating the need to have all expertise in their organization.

*Supporting the participants in the different stages of PBL*

When analyzing how the Challenge Prizes currently present stages and practices that relate to the stages of PBL, we noticed that they offer different types of support that refer indirectly to different stages, even if their design was not purposely based on PBL. For example, the researched Challenge Prizes currently offer workshops, lectures, materials and tools, as well as an opportunity to access mentors and external experts. By doing this, they provide support that is useful for the participants to acquire more specific knowledge as well as for the development of their solution. However, there seems to be a space for improvement of practices that could help the Challenge Prizes to better support the participants in creating their ideas, as well as in reflecting about their experience.

In the first stage, Observation and Information Gathering, according to the learning experts and the PBL theory, there is a need to present the problem/challenge of the learning situation in a clear and specific form. For supporting this stage, the organizers could have available resources for the participants to find further information about the challenge. This research indicates a traditional lecture is often the most effective method for providing initial theoretical knowledge. This stage could also be supported by a workshop for the participants to explore the problem together, allowing the participants to benefit from the diversity of opinions and perspectives.

The second stage, Questions, Ideas and Hypothesis formulation was interpreted to be a phase in Challenge Prizes when the participants can formulate questions and create ideas for the

solution. We searched for signs of the Challenge Prize organizers supporting this stage. According to our interviewees, this stage seemed to be a responsibility of each group. To improve support for idea creation, the Challenge Prize organizers could support the participants in seeing the challenge in different ways. Combined with their previous knowledge they could identify the questions which will be fundamental for the next steps, as mentioned by PBL theory. This could be achieved for example with brainstorming sessions or templates with questions about the challenge.

The third stage, Learning issues or Inquiry Strategy, is a phase where the groups are collaborating between themselves or with other stakeholders to acquire the knowledge they may need for developing a solution. This stage was identified in this research to exist in some form in all Challenge Prizes and be supported by the organizers with workshops, dialogue meetings with stakeholders or by having a database of external experts that could offer the participants specific knowledge related to the topic of the challenge.

The fourth stage, Action Plan, is a phase that is more particular to each group, since it is the actual development of their solutions. In this phase, Challenge Prizes offer tools related to planning and business development for the participants, which is helpful and some of them also already offer mentors. However, the Challenge Prizes could definitely more commonly offer mentors that have been through similar processes and have experience in the field.

The final stage in PBL is Reflection and since it is critical to enhance the overall learning experience, it is discussed further in the subsection below.

*Reflection is essential for learning*

Reflection is perceived as essential for learning according to the learning experts, and in the literature reflection is seen as necessary to address the Sustainability Challenge. According to theory and learning experts, reflection is the last stage of PBL, but it should actually be part of an iterative process, happening throughout the learning experience. The researched Challenge Prizes do not have an intentional reflection process. By intentionally reflecting about their process, the participants could become more aware of their learning, which would enhance deeper learning of the new knowledge, as well as enhance the skills they developed in group work. The achieved deeper learning would also help the participants to apply it to the solution.

The reflection process does not necessarily need to be incorporated into all stages of the Challenge Prize, since this could be overwhelming. However, organizers should consider integrating reflection where it can add additional value by enabling deeper learning which may result in better solutions. One option could be for organizers to support the participants in adopting reflection practices themselves. They could do this by providing reflection templates or questions, or by encouraging reflection within the group. By doing this, organizers could support the participants and assist them in retaining the new learning so they can apply it even after the Challenge Prize. Another option could be to include short reflection moments during events when the participants gather together or on an online platform.

## 4.2.2 The learning conditions

*Diversity*

According to literature and the learning experts interviewed, diversity is important in enhancing innovation. Both the interviewees and theory state it is critical for solving current sustainability problems, as it brings different perspectives together, which can help with

understanding the complexity of the problems the teams are trying to address. The interviewed Challenge Prize organizers also recognized the benefits of having a diverse pool of participants. However, we consider the diversity they advocated to be limited since it was mostly related to different educational backgrounds versus for example representing different age groups, ethnic backgrounds or genders. An example to encourage diversity that was seen in some of the Challenge Prizes can be the rules around the entry requirements for teams. Furthermore, diversity could be increased through offering possibilities for all the participants and teams to collaborate in innovative ways that are suitable for the contest (e.g. video conferencing, social collaboration platforms, etc).

*Collaboration and group work*

Collaboration and group work are a major aspect of PBL. For PBL, group work is a requirement. The Challenge Prizes already understand the benefits of group work. The learning experts mentioned that when working in groups there is a need to create a safe space, which they defined as an open, trusting and non-judgmental atmosphere that encourages inquiry. Thus, to improve collaboration and group work, the Challenge Prize organizers could provide information and guidance on how to create a safe space. This could be done by providing some examples of practices that can create trust and safe spaces in groups. We understood that some Challenge Prizes did not want to interfere in the way that groups work, however they could provide support for them to create a favorable environment for their work. It is important to notice that online interaction is not as good for certain types of learning and group work as interacting in person.

Also, Challenge Prizes could provide the groups with mentors. They are important in the learning process as they can provide the structure for the group process and also guide the idea creation and development process by asking questions. When the mentor has experiences with similar process or in the field, he/she can help the learners by sharing the experiences and inspiring the learners to overcome challenges.

Additionally, having the different groups collaborate between each other could help to bring more benefits of diversity as they would learn from a larger pool of participants. This could happen on an online platform or during workshops and other types of events. These practices were already common in some Challenge Prizes, although more could be done to benefit from them fully.

For example, Challenge Prizes could benefit from opening more spaces and opportunities for the groups to interact. It is understood that the competitive environment may discourage people from interacting but the Challenge Prizes could invest more time and effort on creating the right conditions to foster interaction by creating safe spaces that increase collaboration. Also, it may be advisable for organizers to encourage participants to share their needs and challenges. This could help them become more willing to help each other as everyone is going through the same process.

*Challenges should be complex, realistic and specific*

The learning experts and PBL theory emphasized the need to have a challenge that is specific, realistic and complex in the context of a learning process. According to the learning experts, the way to solve the problem should not be specific but the winning criteria in the contest should. It was common for the Challenge Prizes to have a broad challenge and then for the participants to identify a smaller challenge within the larger one. This was similar to the research findings which show when applying PBL; the problem is sometimes defined by the

learners, based on information presented to them. In a Challenge Prize it is necessary to have a clear and specific challenge in order to define the boundaries of the solutions and the performance standards related to them. This will help the participants have a clearer idea of what they need to learn and develop in terms of solutions in order to effectively address the challenge. Having clear learning goals in mind will help the participants engage and achieve deeper learning.

*Different Forms of Feedback*

Although feedback does not appear strongly in PBL theory, the PBL experts agreed that feedback is essential for deeper learning. Feedback is especially valuable when it is given in earlier stages of the process, since the learners are able to identify what they are doing well and focus on bridging any identified gaps. Researched Challenge Prizes include feedback practices; however they are implemented at later stages and only for finalists. Given this, in order to better support learning and for the creation of better solutions, it would be appropriate to provide the participants with feedback early in the process. The organizers could incorporate feedback throughout the whole Challenge Prize process. Peer to peer feedback could also be incorporated since it can foster further collaboration and it can also be cost effective for the organizers, since it does not require as much working hours from them. The organizers could support this by providing guidance for feedback practice and a rubric for the feedback, since learning experts emphasized that feedback is more effective when there is some guidance on how to do it.

*Summary*

PBL would be more appropriately applied in Challenge Prizes in a subtle way, and the Challenge Prize organizers would benefit from understanding and using it as an inspiration when planning their processes. Currently, many of the Challenge Prizes already include some of the core aspects of PBL, even if the organizers are not aware of the approach as such. They currently have practices and stages that enable learning according to PBL. Some organizers are willing and interested in improving those aspects in order to enhance learning, which can be done with the support of PBL theory.

## 4.3 Could the learning processes of sustainability-oriented Challenge Prizes be changed in order to better facilitate learning about Strategic Sustainable Development? If so, how?

In this research, we identified conditions that are favorable for learning SSD. As explained before, Challenge Prizes already offer conditions in varying degrees that enhance learning. Group work and diversity, which are identified as important for learning SSD, are already encouraged by Challenge Prizes. To integrate SSD into the learning process organizers should consider giving participants an opportunity to learn a foundation of SSD concepts, and the Challenge Prize organizer needs to consider designing the contest in a way that embeds SSD. When the challenge is set in this way, it will allow the deepest learning about SSD for the participants of the contest, since they will be able to implement the theory into solutions.

## 4.3.1 Including SSD in the process of a sustainability-oriented Challenge Prize

The organizers of a sustainability-oriented Challenge Prize need to consider SSD when developing the process of a Challenge Prize. They need to understand how their challenge fits in the larger Sustainability Challenge and understand the Sustainability Principles in order to incorporate them in the winning criteria, along with other challenge specific criteria. The participants need to understand the core concepts of SSD so they can apply them in their solutions to create solutions that can address the larger Sustainability Challenge. For the participants to be able to learn, the organizers need to consider if the environment that they are creating is optimal for learning SSD. The process of the Challenge Prize should include different actions that will allow for the deeper learning such as supporting the participants by providing opportunities to reflect and providing feedback on ideas, supporting them in their group processes, providing and experimentation phase and supporting them in how to create and develop ideas. Some of these actions were already explained in the context of PBL, but others will be explained in more detail below.

*Conditions that support learning SSD*

A non-judgmental and open environment, with a possibility to ask questions and make mistakes, create conditions that are favorable for learning SSD concepts. In this research, it was noticed that these characteristics are probably lacking in the Challenge Prizes we researched. In order to address this, trust building exercises could be integrated into the process. Also, the Challenge Prizes we researched could benefit from varied teaching methods to engage different learning styles and an iterative structure of the learning process, since they were generally lacking in the researched Challenge Prizes. The organizers could take this into account while planning the contest, and use intentional feedback and reflection tasks, as well as help from PBL stages to create an iterative learning process. The Challenge Prize environment would naturally lend itself for exploring different teaching methods through incorporating learning by different methods and embracing the learning by doing nature of the contests.

The prizes that are awarded in the contest can also have an effect on the collaborative atmosphere of the contest. When designing the contest, organizers could consider how the prize can foster a collaborative atmosphere, by rewarding more teams or thinking about how the prize could foster altruistic motivations for example.

*Learning the core concepts of SSD*

According to theory, in order to address the Sustainability Challenge a systems perspective and a focus on principles and concepts are needed. In order to create a Challenge Prize environment that fosters learning about sustainability, it is recommended to offer the participants a thorough foundation of the core concepts of SSD as part of the process of the Challenge Prize, in order to help them create sustainable solutions. Using SSD as a definition for sustainability will allow the participants to have a clear vision of a sustainable solution they are creating. Understanding the Sustainability Challenge and its complexity, together with systems thinking, will allow the participants to see the interconnectedness and complexity of the socio-ecological system. They will also be able to understand that when they are planning their solution, they need to be aware that small changes in the system may lead to unexpected consequences.

When creating their solutions, the Sustainability Principles combined with other challenge specific winning criteria will allow the participants to backcast from this vision and develop

their solution. The FSSD can be used as a tool to support the participants to strategically develop their solutions as they will be able to organize the different concepts they come across when designing their solution and identify any gaps and further opportunities.

In order to educate participants on SSD core concepts, specialized expertise should be considered to convey the first overview of them. SSD concepts can be hard to grasp for a participant who is unfamiliar with them. However, the prior knowledge and background of participants affects how quickly they can learn these concepts and should be taken into account. The Challenge Prize organizers currently support the participants with different kinds of expert knowledge that is related to their particular challenge through offering consultancy from external experts, readings and workshops, showing that there is space for providing information about SSD.

*Process of creating and developing an idea at a sustainability-oriented Challenge Prize*

Before the idea creation process, it is important to explain the larger sustainability challenge to the participants, so they can understand how the challenge in that contest can address it. The initial process of creating the idea would be more appropriate if free and not yet constrained by SPs, since the SSD experts expressed that if the initial creation of solutions starts with the constraints of sustainability principles, it may limit the imagination and creativity of the participants, and they also acknowledged that no solution is ever completely sustainable. Constraining the idea with the SPs would be helpful later in the process, since the boundaries of the Sustainability Principles can act as beneficial restraints and actually enhance creativity.

After understanding the core concepts of SSD, participants can work on an idea formulated at the start of the process or refine an idea they brought into the contest. In any case, they can develop or refine the idea during the process within the constraints of the Sustainability Principles. The SPs should be included in the winning criteria, along with other challenge specific criteria.

One action that would assist in learning SSD and creating better solutions would be experimentation. Theory mentions that Challenge Prizes are a space where experimentation can happen and SSD experts see experimentation as important for learning SSD concepts. The learning experts considered it as a way for the participants to learn by doing and to validate their ideas. However, Challenge Prizes did not provide a phase for experimentation, even though the organizers saw the importance of it. Experimentation would also allow the participants to get user feedback on the ideas, develop better solutions to the challenge as well as learn more effectively by applying theory into practice and learning from their mistakes.

*Summary*

During the research we understood that the most crucial part of adding understanding of sustainability to the Challenge Prizes is defining the challenge and creating appropriate winning criteria. The criteria should encourage participants to create solutions in alignment with the SPs. Based on this research it is possible to envision a Challenge Prize process that would help participants learn SSD.

That process would include SSD in five levels as seen through the lens of the FSSD, which shows a clear overview of a sustainability-oriented Challenge Prize, since the FSSD allows for strategic planning towards sustainability. On the Systems level, in the design of the process of the Challenge Prize, SSD would be taken into account while setting the challenge so that the challenge is understood as part of the larger Sustainability Challenge. The Success level would

comprise of the winning criteria that include the Sustainability Principles and any other criteria deemed important by the organizer. The Strategic level would allow the participants to backcast from the winning criteria as it would be communicated to the participants. The Actions level would consist of the different actions that help creating a learningful process for the participants, for example the participants could be supported with feedback, support for group work, spaces to experiment and encouragement for reflection. The participants would be supported in the creation and development of ideas that would align with the Sustainability Principles, by teaching them the SSD concepts in workshops, online classes, or with videos or readings. On Tools level the participants would be offered tools that help them assess the sustainability of their ideas, for example MSPD and Sustainability Life Cycle Assessment. Table 4.1 shows this in a summarized form.

| Level | Characteristics of Sustainable Challenge Prize |
|---|---|
| Systems | Setting the challenge with larger Sustainability Challenge in mind/Understanding the systems perspective |
| Success | Winning criteria with the SPs (in addition to other possible criteria) |
| Strategic | Communication of winning criteria to participants to allow backcasting |
| Actions | Actions that create a learningful process: support for group work process, offering experimenting, feedback and reflection phases, creating safe spaces for learning, support for finding information on sustainability and challenge related topics. |
| Tools | Tools that help the participants create sustainable solutions: Sustainability Life Cycle Assessment, FSSD (in addition to other tools that are relevant to Challenge) |

*Table 4.1Sustainability Challenge Prize through the lens of the FSSD*

## 4.4 In what way could sustainability-oriented Challenge Prizes, supported by Problem-based Learning, help facilitate learning for Strategic Sustainable Development?

Challenge Prizes have a history of creating scientific and technological breakthroughs (Masters and Delbecq 2008); therefore they can be highly useful to address current problems we have in society. Challenge Prizes can also be utilized to spread awareness on a specific topic. According to this research, sustainability-oriented Challenge Prizes can create positive change towards sustainability in two ways: by growing capacity in people towards moving society to a sustainable future and by creating solutions that are aligned with the SSD approach.

In order to address the sustainability challenge, there is a need for new ways of thinking and for an approach that can help dealing with the complexity of the challenge, by introducing concepts and principles, and offering ways to understand the whole socio-ecological system. SSD is an approach that proposes a clear definition of sustainability, based on principles, and that incorporates concepts such as systems thinking and a framework that are helpful when addressing complex problems. As for sustainability-oriented Challenge Prizes, they hold potential for a space in which people can understand the Sustainability Challenge. If they incorporate SSD thinking in their process that would allow the participants to learn about different ways to address the Sustainability Challenge, therefore they would be able to contribute to a more sustainable society.

According to this research, understanding of the many aspects that are crucial for addressing the larger Sustainability Challenge were missing from the researched Challenge Prizes, for example understanding the larger Sustainability Challenge and its complexity, and understanding of the planet Earth as a socio-ecological system in which everything is interrelated. Therefore implementing SSD could allow the Challenge Prizes to include concepts that will help the participants to understand and define sustainability, grow sustainability related skills, and implement the learned content by creating sustainable solutions.

Learning for sustainability requires deep learning and alternative approaches that allow for cross-disciplinary thinking. PBL is an approach with these characteristics and is also already implicitly found in Challenge Prizes. Therefore, they could benefit from incorporating it in order to design an effective learning process. Also sustainability-related Challenge Prize processes can be supported by Problem-based Learning (PBL), since it gives a structured approach for a learning process that also incorporates factors that are crucial for learning SSD, as has been noticed in previous research (Missimer and Connell 2012) and in this study. The organizers of Challenge Prizes that aim for learning about sustainability would benefit from being aware of the PBL approach and use it as an inspiration when planning their Challenge Prize.

There are some main characteristics that need to be considered in order to create a learningful experience for sustainability. The proposed challenge should be specific, complex and real as mentioned by learning experts and theory. The inclusion of reflection, group work, experimentation phases, creation of conditions that are favorable for learning and collaboration among diverse people in the Challenge Prize process are all essential to PBL and learning the SSD. Having a sustainability-oriented Challenge Prize that is structured around a pedagogical approach that allows the participants to implement the theory into a practical solution will help them to gain skills and knowledge about SSD. Therefore, the participants will be better informed and prepared to contribute for society's movement towards sustainability.

Also, a structured learning process could benefit both the participants in their learning process and the Challenge Prize organizers, due to the higher likelihood of more innovative and better solutions. The systems thinking approach of SSD could allow the organizers to have a clear understanding of how their potential challenge is related to the larger Sustainability Challenge and help them design the contest accordingly. It will also help the participants to consider how their solutions might impact the Sustainability Challenge, by avoiding unexpected consequences.

A realization that emerged during the research was that many of the Challenge Prize organizers actually see the impact of Challenge Prizes in creating public awareness around certain concepts, and therefore motivating large numbers of people to become enthusiastic to learn a certain topic. Learning in Challenge Prizes is different from traditional education and can engage people that would not be interested in taking part in courses or formal education about sustainability. Therefore, sustainability-oriented Challenge Prizes could be an interesting concept for learning sustainability in a fun and innovative way, being problem-based, collaborative, centered around new ideas and interaction among diverse, unlikely stakeholder groups. While the participants create the solutions for the contest, they simultaneously address the larger Sustainability Challenge, and most of all, they are able to learn sustainability related skills that they can use later.

The most important realization that emerged was that sustainability-oriented Challenge Prizes can be very good environments for learning SSD. This is because they allow the learners to

implement the learned content into a solution and understand the theory from a practical viewpoint and by learning by doing, which in turn allows for higher levels of comprehension and is particularly useful for learning the SSD concepts.

Since addressing the Sustainability Challenge requires learning, transformed ways of thinking and opportunities for reflecting the new knowledge, sustainability-oriented Challenge Prizes could be a way to offer a space for this shift in thinking to happen, if they implemented the SSD thinking and created better learning processes.

## 4.5 Recommendations for Challenge Prize organizers

Based on the discussion of the results we created a list of recommendations for Challenge Prize organizers that are planning a sustainability-oriented Challenge Prize. These recommendations can be taken into account while planning the process of the Challenge Prize. We acknowledge that the organizers might not be informed about SSD and we recommend that when willing to create a sustainability-oriented Challenge Prize they need to consult with an SSD expert.

Recommendations related to inclusion of SSD in the Challenge Prize:

- When setting the challenge, it is recommended that the organizers understand the relation of the challenge to the larger sustainability challenge. It is beneficial for the challenge to be complex, realistic and specific.
- Including the Sustainability Principles in the winning criteria, along with other challenge related criteria will help the creation of more sustainable solutions. It is helpful if the participants start their idea creation process without the constraints of the principles, and then modify their idea to align with the principles at later stages in the process.
- Communicating the winning criteria will allow the participants to backcast from it.
- It would be beneficial if tools for sustainability assessment are provided to the participants, so they can assess their own solutions.

Recommendations related to creating a learningful environment:

- The overall process of the Challenge Prize can benefit significantly if the challenge is structured around learning and if the process has an iterative nature.
- Structuring the process of the Challenge Prize based on the PBL stages as an inspiration, and offering support for understanding the challenge, creating an idea, offering expert knowledge on subject matter and offering support for idea development, can be beneficial.
- The process can benefit from having feedback incorporated in early phases and also of incorporating peer-to-peer feedback.
- The organizers would benefit from groups working more effectively, if they support the group process and create the right conditions for collaboration. For example, they should consider providing mentors and guidance around effective group work practices. Encouraging collaboration of all participants and sharing ideas, knowledge and expertise would be beneficial for organizers and participants.
- The organizers would enhance deeper learning if they included reflection phases into the process.
- The organizers would benefit from creating learningful spaces, allowing for non-judgment and trust, in order for the participants to feel safe to ask questions and make mistakes.

- It would be beneficial to include experimentation phases in the process, designed in a way that is appropriate for the challenge, by for example allowing for virtual or physical prototyping.

If these recommendations are taken into consideration by the organizer while planning the Challenge Prize, the participants will likely be able to learn better during the Challenge Prize process and create solutions to the challenges that are more sustainable.

## 4.6 Future Research

Upon completion of our research we realized that there are several areas of potential future research. This is because learning in Challenge Prizes has not been greatly researched. One possible area of future research would be the learning experience from the participants' perspective. And the impact of the learning could be investigated further to explore if the participants achieved deeper learning and whether they are able to use the skills they learned after the contest. Other areas of the Challenge Prize design that also affect learning, for example how the awarded prizes could actually foster altruistic motivations and collaboration instead of competition, could be further investigated.

Another aspect for future research could be how long the duration of the contest should be to in order for the participants to learn and apply SSD. It could also be investigated, whether Challenge Prizes could be used to motivate people to become interested about sustainability and whether the solutions created in Challenge Prizes could actually be within the constraints of the Sustainability Principles.

# 5 Conclusion

It is imperative for humankind to understand the Sustainability Challenge. However, understanding the Sustainability Challenge is just the beginning, since we need to learn ways to address it and to contribute to a more sustainable society. Change towards sustainability requires new ways of thinking and capacity in people to implement the needed changes (Hjorth and Bagheri 2006). In order to move in this direction, there is a need to adopt a holistic perspective that can be achieved by deep learning, which refers to finding underlying meanings and developing analytical skills (Warburton 2003). Sustainability-oriented Challenge Prizes are an environment that has potential to allow people to become aware of the Sustainability Challenge and learn about it. Also, Challenge Prizes are an approach that can foster innovation and positive change through competition (Masters and Delbecq 2008).

This research investigated how Challenge Prize process can facilitate learning about Strategic Sustainable Development with the support of Problem-based Learning (PBL). As understood in this research, sustainability-oriented Challenge Prizes offer a space for addressing the Sustainability Challenge through learning, while also holding potential to produce sustainable solutions as an outcome. They already incorporate many aspects that are needed for learning sustainability, for example diverse participants, interdisciplinary environment, group work, independent learning, and others mentioned before. In order to foster deeper learning about sustainability they should incorporate SSD, so that the participants will be able to understand the complexity of the Sustainability Challenge, adopt a systems perspective and be offered a clear definition for sustainability. In order to further enhance learning for sustainability, the learning processes could be improved by the application of PBL.

While sustainability-oriented Challenge Prize processes offer that space for more people to learn about sustainability, guidance is needed for the Challenge Prizes to reach their full potential in moving society towards sustainability, which could happen through implementing SSD. In this research, we offer recommendations that were based on the information acquired from different learning experts and strongly recommend for the organizers to seek expertise in incorporating SSD.

To include learning for sustainability in their processes, Challenge Prizes can benefit from following a loose structure of PBL and they would benefit from including sustainability into their design by understanding the systemic relationships of the challenge and including the Sustainability Principles into the winning criteria. Also, the learning process of the participants could be supported by teaching core concepts of SSD and including feedback, reflection, experimentation, creation of environments that support group work, collaboration and information finding. Although, learning for the participants is often not the main goal of Challenge Prizes, increasing the participants' knowledge and skills could also result in better, more sustainable solutions and therefore be of interest for the organizers.

Further research on this sustainability-oriented Challenge Prize process is still required in order to see its potential and validity.

We hope that the Challenge Prizes organizers use this information to create a process for their sustainability-oriented Challenge Prizes that will enable the participants to learn about SSD and create more sustainable solutions. Hence, supporting society on the move towards a sustainable future.

# References

Alavi, C. 1995. *Problem-Based Learning in a Health Science Curriculum*. London: Routledge.

Arias-Maldonado, Manuel. 2013. Rethinking Sustainability in the Anthropocene. *Environmental Politics.* Vol 22: 428-446. http://www.tandfonline.com/doi/abs/10.1080/09644016.2013.765161#.VRpLpRxW-ix (accessed 30 March 2015)

Australian Public Service Comission. 2007. *Tackling Wicked Problems: A Public Policy Perspective*. http://www.apsc.gov.au/__data/assets/pdf_file/0005/6386/wickedproblems.pdf (accessed 22 February 2015)

Awang, Halizah and Ishak Ramly. 2008. Creative Thinking Skill Approach Through Problem-Based Learning: Pedagogy and Practice in the Engineering Classroom. *International Journal of Social, Education, Economics and Management Engineering.* Vol 2(4): 26 - 31. http://waset.org/publications/15369/creative-thinking-skill-approach-through-problem-based-learning-pedagogy-and-practice-in-the-engineering-classroom (accessed 22 February 2015)

Ballantyne, Perrie. 2014. *Challenge Prizes: A Practice Guide.* London: Nesta. http://www.nesta.org.uk/sites/default/files/challenge-prizes-design-practice-guide.pdf (accessed 22 February 2015)

Berard, M. T. 2008. Sustainability and economics. *Journal of Vinyl and Additive Technology*. Vol 14: 91. http://onlinelibrary.wiley.com/doi/10.1002/vnl.20160/abstract (accessed 30 March 2015)

Beringer, Jason. 2007. Application of Problem Based Learning through Research Investigation. *Journal of Geography in Higher Education*. Vol 31: 445-457 http://www-tandfonline-com.miman.bib.bth.se/doi/pdf/10.1080/03098260701514033 (accessed 22 February 2015)

Besharov, Douglas J., and Heidi Williams. 2012. Innovation Inducement Prizes: Connecting Research to Policy. *Journal Of Policy Analysis & Management* 31, no. 3: 752-776. Business http://miman.bib.bth.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=76575982&site=ehost-live (accessed February 27, 2015)

Biermann, Frank. 2014. The Anthropocene: A governance perspective. *The Anthropocene Review*. Vol 1: 57-61. http://anr.sagepub.com/content/1/1/57.full.pdf+html (accessed 30 March 2015)

Bogéa, Ricardo. 2015. Interview with authors. Skype. 26 March 2015.

Bojko, Roman. 2015. Interview with authors. Skype. 25 March 2015.

Braun, Virginia and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology. Vol 3: 77 - 101.* http://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa# (accessed 24 April 2015)

Bravo, Jennifer. 2015. Interview with authors. Skype. 20 March 2015.

Broman, Göran, John Holmberg, and Karl-Henrik Robèrt. 2000. Simplicity without reduction: Thinking upstream towards the sustainable society. *Interfaces* 30, no. 3: 13-25. http://www.researchgate.net/publication/255593713_Simplicity_Without_Reduction_Thinking_Upstream_Towards_the_Sustainable_Society (accessed 23 February 2015)

Brown, L., Flavin C and French H. 2000. *State of the world 2000*. Norton, New York.

Brunt, Liam, Josh Lerner, and Tom Nicholas. 2012. Inducement Prizes and Innovation Inducement Prizes and Innovation. *Journal of Industrial Economics* 60, no. 4: 657-696. http://miman.bib.bth.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=84484363&site=ehost-live (accessed 27 February 2015)

Bryman, A. and Bell, E. 2011. *Business research methods*. Third Edition. Oxford: Oxford Univ. Press.

Buckingham-Hatfield, S. 1996. Sustainability and planning. In *Environmental Planning and Sustainability*, Buckingham-Hatfield, S. and Evans, R. (Eds). John Wiley and Sons, Chichester.

Capra, Fritjof. 2005. Complexity and Life. *Theory, Culture & Society* 22(5): 33–44. http://tcs.sagepub.com.miman.bib.bth.se/content/22/5/33.full.pdf+html (accessed 30 March 2015)

Capra, Fritjof. 1985. Criteria of systems thinking. *Futures*. Vol 17: 475-478. http://www.sciencedirect.com.ezaccess.libraries.psu.edu/science/article/pii/001632878590059X (accessed 22 February 2015)

Cartese, A.D. 1992. Education for an environmentally sustainable future. *Environmental Science and Technology*. Vol. 26 No. 6: 1108-14.

Cockrell, Karen Sunday and Julie A. Hughes Caplow. 2000. A Context for Learning: Collaborative Groups in the Problem-Based Learning Environment. *The Reviews of Higher Education*. Volume 23, no 3: 347 - 363. http://muse.jhu.edu.miman.bib.bth.se/journals/review_of_higher_education/v023/23.3cockrell.pdf (accessed 22 February 2015)

Culver, L., Escudero, L., Grindle, A., Hamilton, M. and Sowell, J. 2007. *Policies, incentives, and growth in the newspace industry*. Cambridge, MA: Massachusetts Institute of Technology Working Paper.

Daly, Kellehear and Gliksman. 1997. *The public health researcher: A methodological approach*. Melbourne, Australia: Oxford University Press.

Dow. n.d. Dow Sustainability Innovation Student Challenge Award website. http://www.dow.com/sustainability/studentchallenge/ (accessed 22 February 2015)

Fridberg, Hans. 2015. Interview with authors. Skype. 25 March 2015.

Fu, Qiang and Jingfeng Lu. 2009. How to Motivate Innovation: Subsidies or Prizes? Central University of Finance and Economics. http://www.intertic.org/new_site/wp-content/uploads/Theory%20Papers/fuqiang.pdf (accessed 27 February 2015)

Glass, Amy Jocelyn and Kamal Saggi. 2001. Innovation and wage effects of international outsourcing. *European Economic Review*. Vol 45: 67 - 86. http://www.sciencedirect.com/science/article/pii/S0014292199000112 (accessed 24 April 2015)

Guest, Greg. 2012. *Applied thematic analysis*. Thousand Oaks, California: Sage.

Heatherman, Diego. 2015. Interview with authors. Skype. 23 March 2015.

Hindenburg, Louise. 2015. Interview with authors. Skype. 26 March 2015.

Hjorth, Peder and Ali Bagheri. 2006. Navigating towards Sustainable Development: A systems dynamic approach. *Futures* 38: 74-92. http://www.homepages.ucl.ac.uk/~ucessjb/S3%20Reading/hjorth%20and%20bagheri%202006.pdf (accessed 30 March 2015)

Hmelo-Silver, Cindy E. 2004. Problem-based Learning: What and How do Students Learn? *Educational Psychology Review*. Vol. 16: 235-266. http://link.springer.com/article/10.1023%2FB%3AEDPR.0000034022.16470.f3 (accessed 24 April 2015)

Holmberg, John, and Karl-Henrik Robèrt. 2000. Backcasting from non-overlapping sustainability principles - a framework for strategic planning. *International Journal of Sustainable Development and World Ecology*. Vol 7: 291-308. http://www.naturalstep.org/en/system/files/3b-Backcasting.pdf (accessed 30 March 2015)

Holmberg, J., Lundqvist, U., Robèrt, K-H. and Wackernagel, M. 1999. The Ecological Footprint from a Systems Perspective of Sustainability. *International Journal of Sustainable Development and World Ecology.* Vol 6: 17-33. http://www.thenaturalstep.org/ja/system/files/4d-Eco-Footprint.pdf (accessed 30 March 2015)

Holmes, Allie. 2015. Interview with authors. Skype. 30 March 2015.

Hopwood, B., M. Mellor, and G. O'Brien. 2005. Sustainable development: Mapping different approaches. *Sustainable Development* 13: 8-52. http://onlinelibrary.wiley.com/doi/10.1002/sd.244/abstract (accessed 03 February 2015)

Hussmann, Peter M., Christa Trandum and Martin E. Vigild. 2010. *How to Include Sustainability in Engineering Education? The "Green Challenge" at DTU is one way.* Proceedings of the 6th International CDIO Conference, École Polytechnique, Montréal. http://www.cdio.org/files/document/file/T3B_Paper_4.pdf (accessed 03 February 2015)

Ingenjörer för Miljön. 2008. Guide to the Framework For Strategic Sustainable Development. http://www.ingenjorerformiljon.se/wp-content/uploads/2010/12/080512-Guide-to-the-FSSD.pdf (accessed 24  April 2015)

International Union for Conservation of Nature. 2006. The Future of Sustainability: Re-thinking Environment and Development in the Twenty first Century. *Report of the IUCN Renowned Thinkers Meeting* http://cmsdata.iucn.org/downloads/iucn_future_of_sustanability.pdf (accessed 30 March 2015)

Jacquemin, Alexis. 1995. Capitalism, Competition, Cooperation. *De Economist* Vol 1: 1-14. http://miman.bib.bth.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=17874364&site=ehost-live (accessed 24 April 2015)

Jacobs, M. 1999. Sustainable development: a contested concept. In: *Fairness and futurity: essays on environmental sustainability and social justice*. Dobson, A, ed. Oxford, UK: Oxford University Press.

Kalil, Thomas. 2008. *Prizes for Technological Innovation*. The Brookings Institution. http://www.brookings.edu/~/media/research/files/papers/2006/12/healthcare%20kalil/200612kalil.pdf (accessed 22 February 2015)

Kay, L. 2011. The effect of inducement prizes on innovation: evidence from the Ansari XPrize and the Northrop Grumman Lunar Lander Challenge. *R&D Management*. Vol 41: 360–377. http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9310.2011.00653.x/abstract (accessed 22 February 2015)

Knowledge Ecology International. 2008. *Selected Innovation Prizes and Reward Programs*. KEI Research Note. http://keionline.org/misc-docs/research_notes/kei_rn_2008_1.pdf (accessed 22 February 2015)

MacDonald, Jamie P. 2005. Strategic Sustainable Development using the ISO 14001 standard. *Journal of Cleaner Production.* Vol 13: 631-643. http://www.sciencedirect.com/science/article/pii/S0959652604000459 (accessed 30 March 2015)

Masters, W.A. and Delbecq, B. 2008. *Accelerating Innovation with Prize Rewards: History and Typology of Technology Prizes and a New Contest Design for Innovation in African Agriculture*. International Service for National Agricultural Research. https://www.google.fi/books?hl=fi&lr=&id=IS2QYSqoh6UC&oi=fnd&pg=PR6&dq=+Masters,+W.A.+and+Delbecq,+B.+(2008)+%E2%80%98Accelerating+Innovation+with+Prize+Rewards:+History+and+Typology+of+Technology+Prizes+and+a+New+Contest+Design+for+Innovation+in+African+Agriculture.&ots=G_nBuri_yI&sig=unuS9TODWvpS5p66sgttDVmbDAc&redir_esc=y#v=onepage&q&f=false (accessed 22 February 2015)

Maxwell, A. J. 2013. *Qualitative Research Design: An Interactive Approach*. SAGE publications.

McKenzie, S. 2004. *Social Sustainability: Towards Some Definitions*. Hawke Research Institute, Working Paper Series No. 27, University of South Australia. http://w3.unisa.edu.au/hawkeinstitute/publications/downloads/wp27.pdf (accessed 22 February 2015)

McKinsey and Company. 2009. *And the winner is...Capturing the promise of philanthropic prizes*. http://www.mckinseyonsociety.com/downloads/reports/Social-Innovation/And_the_winner_is.pdf (accessed 22 February 2015)

Merkel, James, and Larry H. Litten. 2007. The sustainability challenge. *New Directions For Institutional Research* 134: 7-26. http://miman.bib.bth.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=afh&AN=26262500&site=ehost-live  (accessed 30 March 2015).

Missimer, Merlina. 2013. *The social dimension of strategic sustainable development*. Ph.D. diss., Blekinge Institute of Technology, School of Engineering. http://www.bth.se/fou/forskinfo.nsf/all/30692df535b84f62c1257b390042ed84/$file/Missimer_lic.pdf (accessed 22 February 2015)

Missimer, Merlina and Tamara Connell. 2012. Pedagogical Approaches and Design Aspects To Enable Leadership for Sustainable Development. *Sustainability: The Journal of Record*. Vol 5(3): 172-181. http://www.bth.se/fou/forskinfo.nsf/all/35015dde222f462ac1257a1c0036fb0f?OpenDocument (accessed 30 March 2015)

Mitchell, G. 1996. Problems and Fundamentals of Sustainable Development Indicators. *Sustainable Development*. Vol 4: 1-11. http://onlinelibrary.wiley.com/doi/10.1002/%28SICI%291099-1719%28199603%294:1%3C1::AID-SD24%3E3.0.CO;2-N/abstract (accessed 30 March 2015)

Nalebuff, B.J. and Stiglitz, J.E. 1983. Prizes and Incentives: Towards a General Theory of Compensation and Competition. *The Bell Journal of Economics*. Vol. 14: 21-43. https://www.google.se/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCkQFjAA&url=https%3A%2F%2Facademiccommons.columbia.edu%2Fdownload%2Ffedora_content%2Fdownload%2Fac%3A148236%2FCONTENT%2F3003535.pdf&ei=SdrtVPX6NuHCywPN3YJQ&usg=AFQjCNHEmZRVampcyhC66BDZG6X7co6A-Q&sig2=cpCaehk_6APJkmX6HXWcWA&bvm=bv.86956481,d.bGQ (accessed 22 February 2015)

Nesta. n.d. The Big Green Challenge website. http://www.nesta.org.uk/project/big-green-challenge (accessed 22 February 2015)

Ny, Henrik. 2006. Strategic life-cycle modeling for sustainable product development, Blekinge Institute of Technology.http://www.bth.se/fou/Forskinfo.nsf/allfirst2/83ca12a0c5e4932dc1257290004d4f95/$file/Ny_lic.pdf (accessed 22 February 2015)

Ny, Henrik, Jamie MacDonald, Göran Broman, Ryoichi Yamamoto, and Karl-Henrik Robèrt. 2006. Sustainability constraints as system boundaries: An approach to making life-cycle management strategic. *Journal of Industrial Ecology* 10, 1-2: 61-77. http://www.bth.se/fou/forskinfo.nsf/all/e2b499c2f7f697d3c1257290004f1555/$file/Ny%20H_2006_Sustainability%20Constraints%20as%20System%20Boundaries_JIE_2006_vol%2010_Issue%201-2_secure.pdf (accessed 03 February 2015)

Parikh, A, K Mcreelis, and B Hodges. 2001. Student feedback in problem based learning: a survey of 103 final year students across five Ontario medical schools. *Medical Education*. Vol 35: 632-636 http://miman.bib.bth.se/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=2009435677&site=ehost-live (accessed 24 April 2015)

Peter, Camaren and Mark Swilling. 2014. Linking Complexity and Sustainability Theories: Implications for Modeling Sustainability Transitions. *Sustainability*. Vol 6: 1594-1622. http://www.mdpi.com/2071-1050/6/3/1594/htm (accessed 22 February 2015)

Phillis, Yannis A and Luc A Andriantiatsaholiniaina. 2001. Sustainability: an ill-defined concept and its assessment using fuzzy logic. *Ecological Economics* 37: 435-456. http://dx.doi.org/10.1016/S0921-8009(00)00290-1 (accessed 30 March 2015)

Porter, Michael E. and Mark R. Kramer. 2011. Creating Shared Value. *Harvard Business Review*. Vol. 89: 62-77

Purewal, Vicki. 2015. *Eyes on the goal: Designing prize competitions for innovation.* Presentation at Pristävlingar som drivkraft för innovation. Stockholm, Sweden. 3 February 2015.

Robèrt, K-H, B. Schmidt-Bleek, J. Aloisi de Larderel, G. Basile, J.L. Jansen, R. Kuehr, P. Price Thomas, M. Suzuki, P. Hawken, M. Wackernagel. 2002. Strategic sustainable development — selection, design and synergies of applied tools. *Journal of Cleaner Production* Vol 10: 197–214. http://www.sciencedirect.com/science/article/pii/S0959652601000610# (accessed 30 March 2015)

Robèrt, Karl-Henrik. 2000. Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other? *Journal of Cleaner Production* 8, 3: 243-254 http://ac.els-cdn.com.miman.bib.bth.se/S0959652600000111/1-s2.0-S0959652600000111-main.pdf?_tid=563afc9c-ac52-11e4-9092-00000aab0f6b&acdnat=1423043216_652686ba88cabdf4e4ab9a2b53aea196 (accessed 22 February 2015)

Robèrt, Karl-Henrik, B. Schmidt-Bleek, J. Aloisi de Larderel, G. Basile, J. L. Jansen, R. Kuehr, P. Price Thomas, M. Suzuki, P. Hawken and M. Wackernagel. 2002. Strategic sustainable development - selection, design and synergies of applied tools. *Journal of Cleaner Production* 10, 3: 197-214. http://ac.els-cdn.com.miman.bib.bth.se/S0959652601000610/1-s2.0-S0959652601000610-main.pdf?_tid=8f68a532-ac52-11e4-83f4-00000aab0f27&acdnat=1423043312_4581c5603c105d9700ce626f27863994 (accessed 22 February 2015)

Sachdeva, J. K. 2009. *Business Research Methodology*. Global media.

Savin-Baden, Maggi, and Claire Howell Major. *Qualitative research: The essential guide to theory and practice*. Routledge, 2013.

Schroeder, Alex. 2004. *The Application and Administration of Inducement Prizes in Technology*. Golden, Colorado: Independence Institute. http://www.i2i.org/articles/IP_11_2004.pdf (accessed 22 February 2015)

Steffen, Will, Richardson, Katherine, Rockström, Johan, Cornell, Sarah E., Fetzer, Ingo, Bennett, Elena M., Biggs, R., Carpenter, Stephen R., Vries, Wim de, de Wit, Cynthia A., Folke, Carl, Gerten, Dieter, Heinke, Jens, Mace, Georgina M., Persson, Linn M., Ramanathan, Veerabhadran, Reyeers, B., Sörlin, Sverker. 2015. Planetary Boundaries: Guiding human development on changing planet. *Science*. http://www.sciencemag.org/content/early/2015/01/14/science.1259855 (accessed 22 January 2015)

Steffen, W., A. Sanderson, P. D. Tyson, J. Jäger, P. A. Matson, B. Moore III, F. Oldfield, K. Richardson, H. J. Schellnhuber, B.L. Turner II and R. J. Wasson. 2004. Global *Change and the Earth System: A Planet under Pressure: Executive Summary*. Stockholm: IGBP Secretariat.http://www.igbp.net/download/18.1b8ae20512db692f2a680007761/IGBP_ExecSummary_eng.pdf (accessed 03 February 2015)

Steinemann, Anne. 2003. Implementing Sustainable Development through Problem-Based Learning: Pedagogy and Practice. *Journal of Professional Issues in Engineering Education and Practice*. 217 - 224. http://reforma.fen.uchile.cl/Papers/Implementing%20Sustainable%20Development%20through%20Problem-Based%20Learning%20-%20Steinemann.pdf (accessed 22 February 2015)

Sustainergies. n.d. Sustainergies website. http://sustainergies.se/ (accessed 22 February 2015)

Tainter, Joseph A. 2006. Social Complexity and Sustainability. *Ecological Complexity*. Vol 3: 91 - 103. http://www.sciencedirect.com.miman.bib.bth.se/science/article/pii/S1476945X0600002X (accessed 22 February 2015)

The Sustainable MBA. n.d. *Sustainability Contests and Challenges*. http://www.thesustainablemba.com/classroom/teaching-resources/sustainability-contests-and-challenges (accessed 22 February 2015)

Tislerics, Elena. 2015. Interview with authors. Skype. 1 April 2015.

Turner, Daniel W. 2010. Qualitative Interview Design: A Practical Guide for Novice Investigators. *The Qualitative Report*. Vol 15: 754-760. http://www.nova.edu/ssss/QR/QR15-3/qid.pdf (accessed 22 February 2015)

UNEP. 2012. *Global Environment Outlook 5: Environment for the future we want*. Malta: Progress Press. http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_en.pdf (accessed 03 February 2015)

United Nations. 2011. *World Population Prospects: The 2010 Revision*. United Nations, Department of Economic and Social Affairs, Population Division, New York. http://esa.un.org/wpp/documentation/pdf/WPP2010_Volume-I_Comprehensive-Tables.pdf (accessed 23 February 2015)

van den Bosch, S. 2010. *Transition Experiments: Exploring societal changes towards sustainability*. Rotterdam: Erasmus Universiteit Rotterdam

Warburton, Kevin. 2003, Deep learning and education for sustainability. *International Journal of Sustainability in Higher Education*, Vol. 4: 44 - 56. http://www.emeraldinsight.com.miman.bib.bth.se/doi/pdfplus/10.1108/14676370310455332 ( accessed on 03 June 2015)

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press: Oxford. http://www.un-documents.net/our-common-future.pdf (accessed 03 February 2015)

World Wildlife Fund. n.d. *Stern Review: The Economics of Climate Change*. http://www.wwf.se/source.php/1169158/Stern%20Summary_of_Conclusions.pdf (accessed 30 March 2015)

Yin, R. 2009. *Case Study Research: design and methods*. Thousand Oaks: CA Sage.

# Appendix A: Exploratory Interviewees

The following table is a list of the exploratory interviews conducted with the Challenge Prizes organizers.

| Challenge Prize | Person Interviewed | Position | Country | Short description of the Challenge Prize |
|---|---|---|---|---|
| Innonatives | Ursula Tischner | Manager at European Sustainability Maker Project | Germany | The process of this Challenge Prize happens online, and includes several sustainability related challenges running simultaneously. They accept both individuals and groups to compete. The prize they offer depends on the challenge. |
| Challenge Prize Brazil | Cesar Levy Franca | Founder of the challenge | Brazil | This challenge will be based in an academic setting which aims at teaching sustainability. This challenge is still in its developing stages therefore not much detail about it was provided. |
| Students competition | Clare Mills | Project Manager | Sweden | SC is an organization which organizes different challenges and therefore has different processes depending on the challenge. They have been working with Challenge Prizes for years. They accept both individuals and groups to compete. The prize they offer depends on the challenge. |

# Appendix B: Gap Analysis

This table shows how the information acquired from the exploratory interviews and from the literature review was organized and what questions arose.

| Level | Questions that arose |
|---|---|
| **Systems - Challenge Prizes:**<br>• The global socio-ecological system (society within the biosphere)<br>• Participants<br>• Good definition of the challenge (Specific, Complex, Realistic)<br>• Prize<br>• Different stages in the process | Do they relate their challenge to the bigger sustainability challenge?<br><br>Who are the participants?<br><br><span style="color:red">How does the Challenge Prize process look like?</span><br><br>What Prize do they give? |
| **Success:**<br>• A society that complies with the Sustainability Principles<br>• Winning Criteria<br>• Their overall purpose | Do they have a clear winning criteria?<br><br>Do they include sustainability in their winning criteria?<br><br><span style="color:red">What is</span> their overall purpose learning? |
| **Strategic Guidelines:**<br>• Backcasting from success; the three prioritization questions (as a minimum)<br>• Communicating the winning criteria (definition of success) | Do they communicate the winning criteria? |
| **Actions:**<br>• The actions that help move the global socio-ecological system towards sustainability<br>• Experimenting<br>• Creating possibilities to learn SSD<br>• Creating diverse groups<br>• Supporting the participants<br>• Creating possibilities for interaction<br>• Giving feedback<br>• Reflecting<br>• Creating workshops | Do they have actions that support the participants to learn?<br><br>Do they have actions that give feedback to the participants?<br><br>Do they have space for reflection?<br><br>Do they have space for experimenting? |
| **Tools:**<br>• The tools that support efforts to reach global sustainability<br>• FSSD<br>• Group work tools<br>• Facilitation tools<br>• Assessment tools<br>• Strategic models | Do they offer tools to support the participants in the different actions? |

# Appendix C: Interview Questions

Following are the interview questions asked to each set of interviewees.

**Questions for SSD Experts**

Please explain a little about yourself and your experience of teaching SSD concepts.

*Key components of SSD*

When you have limited time, what are the most important SSD concepts to teach in order to develop a sustainable idea?

Is there an optimum order to teach the SSD concepts? If yes, what is your process for doing this?

*Learning environment for SSD*

What methods do you use to teach SSD?

What are good characteristics of the interaction in the process for learning about SSD? We would like to focus on the importance of the student's autonomy and on the other hand group work and what impacts these aspects of the learning process?

How do you see the role of an advisor or external expert in a learning process?

Is there a phase for reflection and feedback in the learning situation and how does that work?

What kind of tools do you use to teach SSD concepts?

*PBL*

Do you use a PBL approach on your teaching? How do you use it and in which context? Do you use it for teaching about SSD?

The stages of PBL are: (1) Observation or information gathering; (2) Questions, ideas and hypothesis formulation; (3) Learning issues/inquiry strategy; (4) Action plan; and (5) Reflection.

Do you use the stages of PBL and how does that look like in the process?

Is there an experimenting phase?

*Applicability of SSD*

In our context the participants of the Challenge Prize will have to come up with a product or service during the competition.

How can you assess the application of SSD theory on the solution (maybe a product or service)? How is the learning of SSD applied to a practical solution?

How does the fact that a Challenge Prize is competition affect learning of the SSD? What are the benefits and limitations in your opinion?

In the Challenge Prize, the participants are developing solutions for the proposed challenge. Based on your experience, how can we best create a learning process for SSD concepts in order for the participants to create solutions in alignment with an SSD approach?

Is there something else you would like to add?

**Questions for PBL Experts**

Please explain a little about yourself and your experience on using PBL.

*Key components of PBL*

What are the best practices you have noticed when using PBL for teaching? Can you give us some concrete examples of it?

If there is limited time, can this approach work well?

*Learning environment based on PBL*

What are good characteristics of the PBL process that can create a positive environment for learning?

How do you see the role of a mentor in a PBL learning process?

*Learning supplements*

What kind of tools do you use to support your PBL approach to teaching?

*Applicability of PBL*

The stages of PBL are: (1) Observation or information gathering; (2) Questions, ideas and hypothesis formulation; (3) Learning issues/inquiry strategy; (4) Action plan; and (5) Reflection.

How do you see that the PBL stages can be useful for the participants in the contest?

*PBL and experimenting*

How can experimenting be included in these stages?

*PBL and sustainability*

Based on your experience, how can we best create a learning process for a Challenge Prize that will enable the participants to learn about sustainability by using a PBL approach?

*Summary questions*

How could we apply aspects of PBL into the Challenge Prizes?

Are there other learning approaches that can also be useful in this context? If so what are they?

Is there something you would like to add?

**Questions for Challenge Prizes**

Please tell a little about your role in the organization.

*General questions about the Challenge Prize*

Tell us about your Challenge Prize in general.

What is the main goal/purpose of your Challenge Prize?

*Process*

Describe the process of your Challenge Prize. What kind of stages do you have in your process? Are there organized workshops? Why have you chosen to organize your contest in this way?

How do the participants interact during the contest with each other and with the organizers? Is there a web platform or do they meet in person?

What impact do you see with this process on the participants?

Can you describe how the idea is developed in the process of your contest? Can you give us a concrete example of what could happen?

What are the criteria for winning, and how is that communicated to the participants? How do they know if their solution is good?

*Group work and participants*

Do the participants work in groups? Can you describe this?

Are the participants from diverse backgrounds? What are the limitations and benefits in this case?

*Support*

Do the participants have mentors or other external experts? If yes, how you work with the mentors or how the participants interact with the mentors? If not, why not? Do you think it would add anything to your process?

Is there a system of getting/giving feedback in the contest for the ideas/projects? (If yes) How does it work?

*Learning*

Is there any content that you teach during the contest? If yes, how do you teach it? Even if not, what do you think of including a learning phase as a quick course in order to create better solutions in the end?

How do you help the participants gather information relevant to the Challenge during the contest?

What kind of tools do you offer to the participants to help with the development of their solution?

Is there any assumed knowledge level of the participants? Is there any ways in which you ensure a certain level of understanding of the participants?

*Experimentation*

Do the participants have a possibility to experiment with their ideas during the competition and can you tell us more about it?

*Sustainability*

Do you work with sustainability? If yes, how do you define sustainability and communicate it to the participants? How do you and the participants assess their designs from a sustainable perspective?

*Summary questions*

Have you organized this Challenge Prize several times? What have you changed? What has worked? What has not worked?

Is there anything else you would like to add?

# Appendix D: Learning Experts Interviewees

The following table shows the learning experts interviewed.

| Interviewee | PBL/SSD | Position |
|---|---|---|
| **Göran Broman** | SSD | Professor at the Department of Strategic Sustainable Development of Blekinge Institute of Technology |
| **Merlina Missimer** | SSD | Program Director of Master Program in Strategic Leadership towards Sustainability at Blekinge Institute of Technology |
| **Pierre Johnson** | SSD | Project Assistant at the Department of Strategic Sustainable Development of Blekinge Institute of Technology |
| **Tamara Connell** | SSD | Director, Sustainability Learning Programs at The Natural Step Canada |
| **Åse Nygren** | PBL | Education Developer at Blekinge Institute of Technology |
| **Peter Sims** | PBL | Team leader at KaosPilot |
| **Martin Jarl** | PBL | Lecturer at the Department of Health at Blekinge Institute of Technology |

# Appendix E: Challenge Prizes interviewees

| Challenge Prize name– Country | Interviewee | Purpose of Challenge Prize | Type of participants | Times the contest has happened | Prize | Process Description |
|---|---|---|---|---|---|---|
| **Green Challenge** (**GC**) – Denmark | Louise Hindenburg, Manager of Project Groups | Educate the engineers to think about sustainability. | Students from the Technical University of Denmark and partner institutions. They can apply in groups or individually. | 3 | There are 8 categories and 3 winners in each. The first prize is 15000 DKR, the second is 10000 DKK and 5000 DKR for the third prize. | Green Challenge is a competition promoted to the students of the Technical University of Denmark. The competition per se does not have an actual process, since it is nested in the university context. The competition is launched on a Green Week that happens in campus with sustainability related activities for the students and the communication that they can apply for the Green Challenge. The students submit their projects, which must be rooted in their own field and have sustainability, the environment or climate technology as its focal point. In the end, there is an award ceremony with the jury and other stakeholders, where the students have the opportunity to present their projects and network. Green Challenge lasts for one school year. |
| **Nordic Built Challenge** (**NC**) – Based in Norway, with competitions in Denmark, Finland, Iceland and Sweden | Hans Fridberg, Senior Advisor | Encourage innovation and the development of sustainable, viable and scalable refurbishment concepts for some of the most common building types in the Nordic region. | Groups of individuals or organizations/ companies. | 1 | The winners receive an agreement with the building owners to implement their project as well as a monetary prize. There is one winner per country. | The participants need to propose a renovation project for defined buildings in each country. They have the opportunity to have dialogue meetings with the owners of the buildings. The competition takes 10 months. It happens in two stages, first an open application and then four finalists are chosen in each country and then there is a final jury and the communication of the winner. |

| Challenge Prize name– Country | Interviewee | Purpose of Challenge Prize | Type of participants | Times the contest has happened | Prize | Process Description |
|---|---|---|---|---|---|---|
| **Social Impact Award Austria** (SA) – Austria | Diego Heatherman, Social Impact Award Coordinator | Raise awareness for social entrepreneurship, offer an educational program guiding from vague intentions to a social venture, give access to networks of peers & professionals and directly support the most promising ventures. | Students that apply individually or in groups. | 7 | There are 5 winners that receive 3000 EUR. They also become members of the Impact Hub Vienna, receiving support from them to develop their project. | There is a kick-off and meet the founders event. Following that, the participants have the opportunity to participate in workshops about varied topics (for example, introduction to social entrepreneurship, business modelling). There is also a "Meet the jury" event. The participants need to develop an idea of a social enterprise that has social impact in Austria. The competition starts in January and ends in May with an award ceremony. |
| **Social Impact Award Czech Republic** (SC) – Czech Republic | Roman Bojko, Social Impact Award Coordinator | Raise awareness for social entrepreneurship, offer an educational program guiding from vague intentions to a social venture, give access to networks of peers & professionals and directly support the most promising ventures. | Individuals that apply individually or in groups (in that case they need to have at least one student in the group) | 3 | There are 6 winners that receive a monetary award and also the opportunity to join a bootcamp. They also receive a membership of the Impact Hub in Czech Republic and support from them. | There is a kick off and meet the founders event. Following that, the participants have the opportunity to participate in workshops of varied topics (for example, introduction to social entrepreneurship, business modelling). There is also a "Meet the jury" event. The participants need to develop an idea of a social business that has social impact in Czech Republic. The competition starts in January and ends in May with an award ceremony. |
| **Solar Challenge Brazil** (SBC) – Brazil | Ricardo Bogéa, Communication Coordinator | Create awareness about solar energy. | Group of students. | 9 | The winner receives the opportunity to go to the Solar Challenge that happens in Monaco. | The competition is a race between boats powered by solar energy. There is not a process per se only the actual event for the race, which lasts three days. |

| Challenge Prize name– Country | Interviewee | Purpose of Challenge Prize | Type of participants | Times the contest has happened | Prize | Process Description |
|---|---|---|---|---|---|---|
| **Technovation** (TV) – Based in the USA, open to participants from all over the world | Allie Holmes, Events and engagement director | Engage girls to learn technology. | Girls from elementary or high school from any country in the world. They can apply individually or in groups. | 6 | The winning team receives 10000 USD. | The participants need to develop an app that will contribute to solving a community problem. The girls have the option to ask a mentor to support them and they also have a curriculum to guide them through the process. The competition lasts for 12 weeks and ends with an event in San Francisco with 10 finalists and the communication of the winner. |
| **Wege Prize** (WP) – United States of America | Elena Tislerics, Chief of Communications Officer | Create solutions for wicked problems. | Groups of students, which need to be from different programmes. | 2 | There are three winners: the first one receives 15000 USD, the second 10000 USD and the third 5000 USD | It is a transdisciplinary design competition and the participants are all students. They need to develop a project including the concept of circular economy. They have workshops along the way about topics related to skills and subjects that might be useful for the competition. The competition starts with the setting of the challenge and the formation of teams. It ends with an event when the finalists present their project. |
| **XPrize** (XP) – United States of America | Jennifer Bravo, Senior Manager, Prize Development | Capture the world's imagination and inspire others to reach for similar goals, spurring innovation and accelerating the rate of positive change. | Anyone | They run competitions since 1990 | Monetary prize, number of winners and value depends on the particular competition. | They promote several competitions and the process differs between them as well as the duration. Most of it is left to the teams, the organizers promote team summits, field tests and award ceremonies. |

# Appendix F: List of Codes

| Codes | SSD | PBL | CP | Codes | SSD | PBL | CP |
|---|---|---|---|---|---|---|---|
| Group work (importance of) | x | x | x | Interaction between groups | x | x | x |
| Group work conditions | x | x | | Interaction with the organizer | | | x |
| Group formation | | | x | Interaction with other stakeholders | | | x |
| Group work practices | | | x | Feedback | x | x | x |
| Diversity in group | x | x | x | Methods of teaching | x | x | x |
| Reflection | x | x | x | Learning process | x | x | x |
| Mentors (process support) | x | x | x | Prize | x | | x |
| External experts (subject knowledge) | x | x | x | Content taught in a Challenge Prize | | | x |
| Support for information finding | x | x | x | Challenge Prize as creating public awareness | x | | x |
| Core concepts of SSD | x | | x | Inspirational Impact | | | x |
| Time for learning the content | x | x | | Overall purpose of the | | x | x |
| Duration of process | | | x | Learning conditions | x | x | |
| Stages of CP process | | | x | Number of winners | | | x |
| Idea formation | x | x | x | Learning in a competition | x | x | |
| Idea development | x | x | x | Nature of problem | x | x | x |
| Experimentation | x | x | x | Prior knowledge level | x | x | |
| Communication of winning criteria | x | | x | Diversity among the participants | | | x |
| Winning criteria | | x | x | Stage 1 PBL | x | x | x |
| Assessing the solutions with SSD/evaluation | x | | x | Stage 2 PBL | x | x | x |
| Definition of sustainability | x | | x | Stage 3 PBL | x | x | x |
| Setting the challenge/ goal | x | | x | Stage 4 PBL | x | x | x |
| Tools developing ideas | x | x | x | Collaboration | x | x | x |
| Tools for teaching | x | x | x | PBL in general | x | x | |