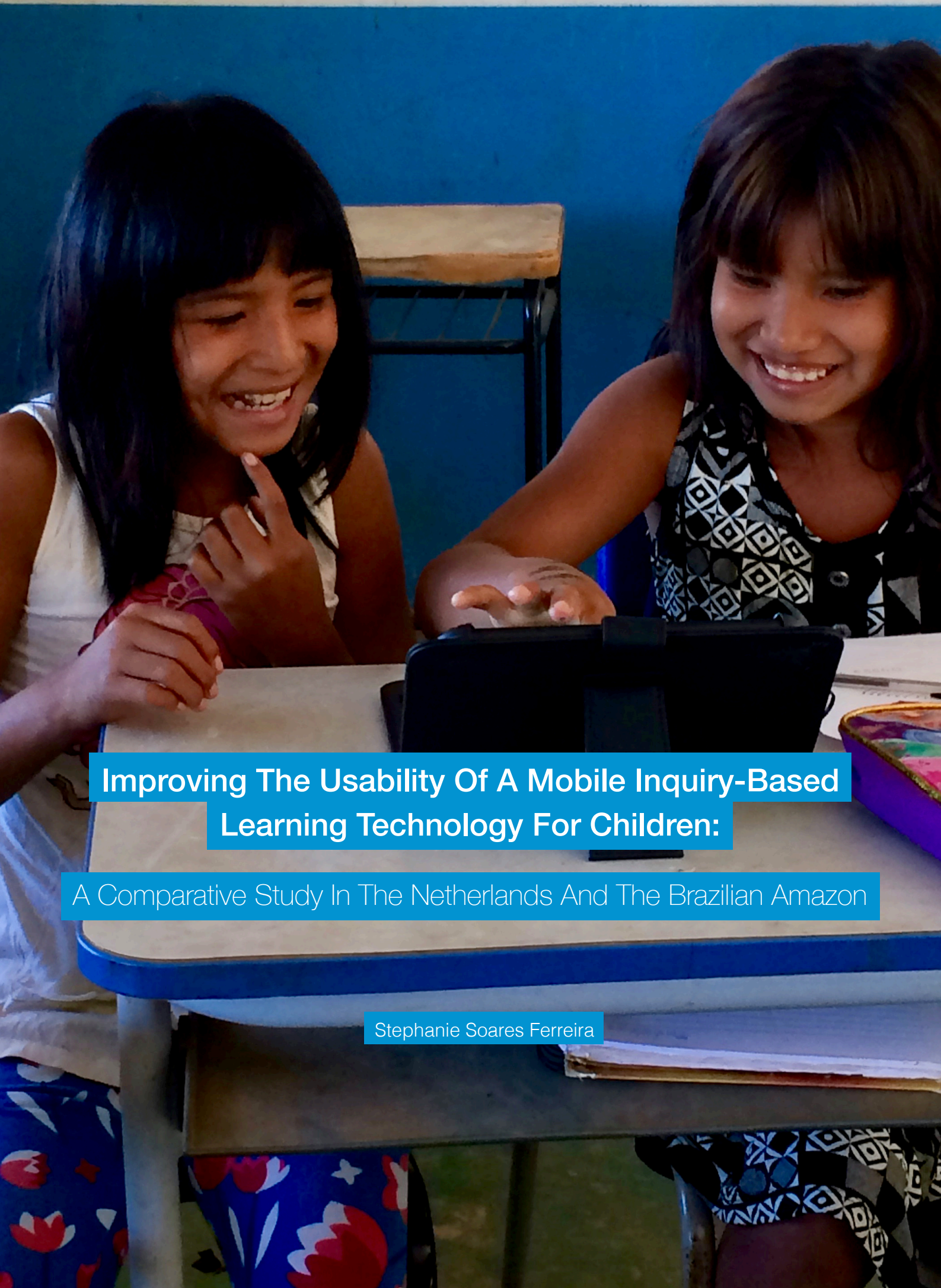

Improving The Usability Of A Mobile Inquiry-Based Learning Technology For Children:

A Comparative Study In The Netherlands And The Brazilian Amazon

Stephanie Soares Ferreira

Master's Thesis

IMPROVING THE USABILITY OF A MOBILE INQUIRY-BASED LEARNING TECHNOLOGY FOR CHILDREN:

A COMPARATIVE STUDY IN THE NETHERLANDS AND THE BRAZILIAN AMAZON

Stephanie Soares Ferreira

Supervisors:
Dr. Joyce Karreman (first supervisor)
Dr. Thomas van Rompay (second supervisor)

Master of Science
Communication Studies

Specialization: Technical Communication

Faculty of Behavioral, Management and Social Sciences

University of Twente
The Netherlands

August, 2017

Abstract

Inquiry-based mobile learning technologies can help children all over the world to enhance their critical thinking and to ask critical questions. However, used without minimal guidance, these technologies may fail in achieving their goal. Previous studies have advocated the incorporation of instructional features in these technologies to better support students' cognitive processes, such as prompts, cues, and goal-lists. However, these instructions may enhance cognitive load, or they are perceived as too restrictive. In order to amplify the understandings of how to support a mobile inquiry-based learning platform for children, especially from poor areas in developing countries, this study investigated, designed and evaluated a new instructional feature for SMILE (Stanford Mobile Inquiry-based Learning Environment). This new feature, named Puzzle Model, is based on Bloom's taxonomy and encompasses question starters designed as puzzle pieces from which students need to form the beginning of questions and complete them with their own words.

The research featured an interactive usability method and had three main phases: exploratory, prototyping, and evaluation. The usability test was done in two elementary schools. One was located in the Brazilian Amazon, and, as a matter of comparison, the other school was located in a medium-size city in the Netherlands. The students from the Amazon were from a remote village and had no prior experience using digital technologies at school, differently from the students from the Netherlands. A 2x2 factorial experiment was conducted in order to assess students' effectiveness and efficiency in creating questions with the Puzzle Model, in comparison to its basic version. Also, a focus group was administered to assess students' perceived satisfaction, after the experiment. In total, 40 students from both schools participated.

Results suggested that the Puzzle Model was effective for all students in the experimental group regardless of their location. Similarly, it was efficient for all the students in the experimental group. However, it was more efficient for the students of the Netherlands. Lastly, the results from the focus groups suggested that, in general, students from both experimental groups were satisfied using the Puzzle Model. Nevertheless, students from the Netherlands reported a higher level of satisfaction, since they mentioned fewer difficulties in operating the system, in comparison to the students from the Amazon who reported more digital skills-related problems. In sum, the results revealed that the Puzzle Model is usable for children from the Amazon and from the Netherlands, with a higher usability for the Dutch students due to their familiarity with digital technologies. As a contribution, this study provides students and teachers with a tool that has the potential to facilitate and gradually improve their inquiry process via the "puzzle question starters". For future studies, it is advisable to measure children's digital skills and investigate whether this may have an impact on their perceived satisfaction, efficiency, and effectiveness. For the latter, studies including a paper prototype of the Puzzle Model would be ideal.

Keywords: usability, inquiry-based learning, mobile technologies, critical thinking, indigenous people, sustainable development

Table of Contents

1. Introduction 2
    1.1 Using SMILE 4
2. Case Description 7
3. Theoretical Framework 9
    3.1 Bloom and the Path to Critical Thinking 9
    3.2 Inquiry-Based Learning Technologies 10
    3.3 Usability for Mobile Learning 11
4. Exploring SMILE (Phase I) 13
    4.1 Challenges 13
    4.2 Possible Solutions 15
5. The Puzzle Model (Phase II) 17
6. Usability Evaluation (Phase III) 19
    6.1 Method 19
        6.1.1 Variables 19
        6.1.2 Hypotheses 20
        6.1.3 Study Design 21
        6.1.4 Participants 21
        6.1.5 Procedure 22
    6.2 Results 25
        6.2.1 Effectiveness 25
        6.2.2 Efficiency 28
        6.2.3 Satisfaction 30
7. Discussion and Conclusion 33
        7.1 Implications of the study and directions for future Research 36
References 38
Appendices 42
    Appendix 1 - Puzzle questions by level in English, Portuguese and Dutch 42
    Appendix 2 - Questions per level of Bloom's taxonomy 45
    Appendix 3 - Lecture Slides in Dutch and in Portuguese 52
    Appendix 4 - Quiz Climate Change 55

1. Introduction

Sustainable development has become the directing principle towards long-term global development. Defined as “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), it aims to achieve a balance in economic and social development together with environmental protection. The 17 Sustainable Development Goals (SDGs), set by the United Nations (UN) in 2015, highlight the critical situation of the planet and call for action in areas of critical importance to humanity. Two factors can play a crucial role in the achievement of global development: education, as a pathway to a critical understanding, and digital technologies, as the tools able to provide quality content and stimulate reflection anytime, anywhere. A combination of both factors to tackle the world's most pressing problems, such as climate change, is addressed in this study.

A range of projects have used Information and Communication Technologies (ICTs) to address the SDGs. These projects are covered under ICT for Development (ICT4D). Among the recent innovations in digital technologies, mobile devices, due to their affordability, portability, and interactive-ness, have been acknowledged as being able to provide opportunities in promoting sustainable development. “The rise of mobile technology and other innovations have made it easier and more cost-effective to deliver critical services in hard-to-reach communities and to expand opportunities for the children and families at greatest risk” (UNICEF, 2016, p. 04). As an example, mobile technologies have been widely used to provide high quality learning opportunities to young learners, even in places where educational resources are scarce, such as poor and remote communities (Kim et al., 2011).

However, the presence of mobile technologies in educational settings and sufficient digital skills do not guarantee that students’ critical understanding and problem-solving skills will be stimulated to tackle the worlds’ problems. Actually, if not integrated to innovative pedagogical practices, technology will mainly reinforce existing educational practices (Albirini, 2007; Salomon, 2002), which traditionally fail to encourage critical thinking in students (Paul, 1992). In order to overcome such problems, inquiry-based learning (IBL) technologies have integrated inquiry-based pedagogical practices in digital environments to enhance students’ critical thinking. Previous studies have reported the effectiveness of mobile technology-integrated IBL systems in different contexts to engage students in practices of collecting and analyzing information, creating their own inquiries, and exploring solutions within their own context (Buckener & Kim, 2014; Hwang et al., 2012; Shih, 2010; Ucar & Trundle, 2011).

Although mobile technology-integrated IBL may present as a solution, shortcomings in implementing these interventions in school learning are also reported in previous studies, raising the question on how to successfully integrate new technologies and pedagogical practices for critical thinking. The reported problems range from mere technical problems in terms of functions of the mobile devices and connectivity to more complex problems, such as lack of teachers’ and students’ familiarity with IBL pedagogical practices and the accordingly high-level effort demanded from them to progress in these practices. To better support technology-integrated IBL practices, previous researchers have advocated the incorporation of instructional features in these technologies, like prompts, goal-lists, templates, hints, and cues, as a supporting tool to drive students’ cognitive processes and

help them to engage in progressive critical thinking (Lakkala, Lallimo & Hakkarainen, 2005; Li & Lim, 2008; Manlove, Lazonder & Jong, 2009). However, as pointed out by Strijbos, Martens, and Jochems (2004), these instructional features may increase students' cognitive load and/or result in a very restricted activity. In that regard, the usability of these features should be carefully examined in order to guarantee the development of user-friendly technologies.

The main aim in this study was to amplify the understandings of how to support a mobile inquiry-based learning platform in order to help children to ask better questions, and thus, enhance their critical understanding and problem-solving skills regarding the world's most critical problems, such as climate change. The focus is particularly on elementary students from poor areas in developing countries since they are the ones with less digital experience, educational resources, and opportunities. However, in order to broaden this understanding, children from developed countries who have experience with digital technologies as part of their education and have more educational resources available will also be considered. In order to achieve that, this study investigated, designed, and evaluated a new instructional feature for SMILE[1] (Stanford Mobile Inquiry-based Learning Environment). As a mobile inquiry-based learning platform, SMILE was designed by Stanford University (USA) to enhance students' critical thinking skills by helping them to create, answer, and reflect on inquiries of different topics.

SMILE is currently in the testing phase, and its effectiveness as an educational intervention has been researched in various contexts in 25 countries. Several of these studies have been piloted by the international non-profit organization Seeds of Empowerment[2] together with Stanford University, especially in under-resourced areas of the developing world. Although the results indicated that even students with little experience in using mobile devices could be adjusted to the technology after a short initial exploration (Buckner & Kim, 2014), challenges persist in how to help them to create higher-order thinking questions. Thus, these challenges will be addressed in this research.

Hence, this study designed a new feature of SMILE, named Puzzle Model, aimed at facilitating the process of creating questions and stimulating critical thinking. The Puzzle Model encompasses 30 question starters designed as puzzle pieces from which students need to form the beginning of questions and complete them with their own words. The puzzle models are adapted from the 6 hierarchical levels of Bloom's Taxonomy (Bloom et. al, 1956). The research featured an interactive usability method and had three main phases: (Phase I) exploratory phase, when the challenges of SMILE for students from underserved communities were assessed; (Phase II) prototyping phase, when the new feature of SMILE was designed and incorporated in its current version; and (Phase III) a convergent phase, when a usability evaluation of the Puzzle Model was tested in comparison to SMILE's basic version.

The usability evaluation was conducted in two elementary schools. One was located in the Xingu Indigenous Reservation, in the south of the Amazon Rainforest in Brazil, and as a matter of comparison, the other in a school located in a medium-size city in the central-eastern part of the Netherlands. They differ in many dimensions, respectively: urbanicity (rural/urban), economic development (low income/developed), and use of mobile devices at

[1] https://gse-it.stanford.edu/smile

[2] www.seedsofempowerment.org

school (daily/never). The idea of comparing the children from both locations was to understand whether the Puzzle Model would be only usable for the children in the Amazon, or, if this new feature would also be useful for children from a developed country who have experience with digital technologies as part of their education and have more educational resources available.

The usability evaluation model was developed based on the definition of ISO 9241-11 (International Standards Organization, 1994), which proposes the assessment of usability by its three sub-constructs: effectiveness, efficiency, and satisfaction. A 2x2 factorial experiment was done in both schools in order to assess students' effectiveness and efficiency in creating questions with the Puzzle Model, in comparison to its basic version. Also, a focus group was administered to assess students' perceived satisfaction after the experiment.

Research goals:
Amplify the understandings of how to support a mobile inquiry-based learning platform in order to help children ask better questions, especially students from poor areas in developing countries, but also comparing with students from developed countries.

Research questions:
Taking into account children from the Amazon and students from the Netherlands:
To what extent is the Puzzle Model usable for these students?

a. Is the Puzzle Model effective for them?
b. Is the Puzzle Model efficient for them?
c. Are these students satisfied with it?

1.1 Using SMILE

SMILE is a mobile educational technology designed by Stanford University to promote higher-order learning via a mobile inquiry-based model of peer collaboration (Kim et al., 2011). The model proposed by SMILE sets critical thinking as a learning activity in which teachers and students can explore any topic via inquiries. It is highly flexible: the inquiry activities can be created on any topic, can be structured to open inquiries, offering a maximum flexibility and freedom for learners to set goals, to define results, and to organize the inquiry process. A SMILE session comprehends a cyclical model (Figure 1) towards which students are guided to think about a topic, formulate questions, share with peers, solve and evaluate each other's inquiries, reflect, and exchange knowledge.

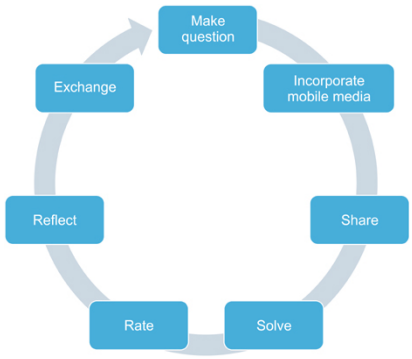

Figure 1. SMILE model and the constituent phases of the inquiry process (Kim & An, 2016, p.167).

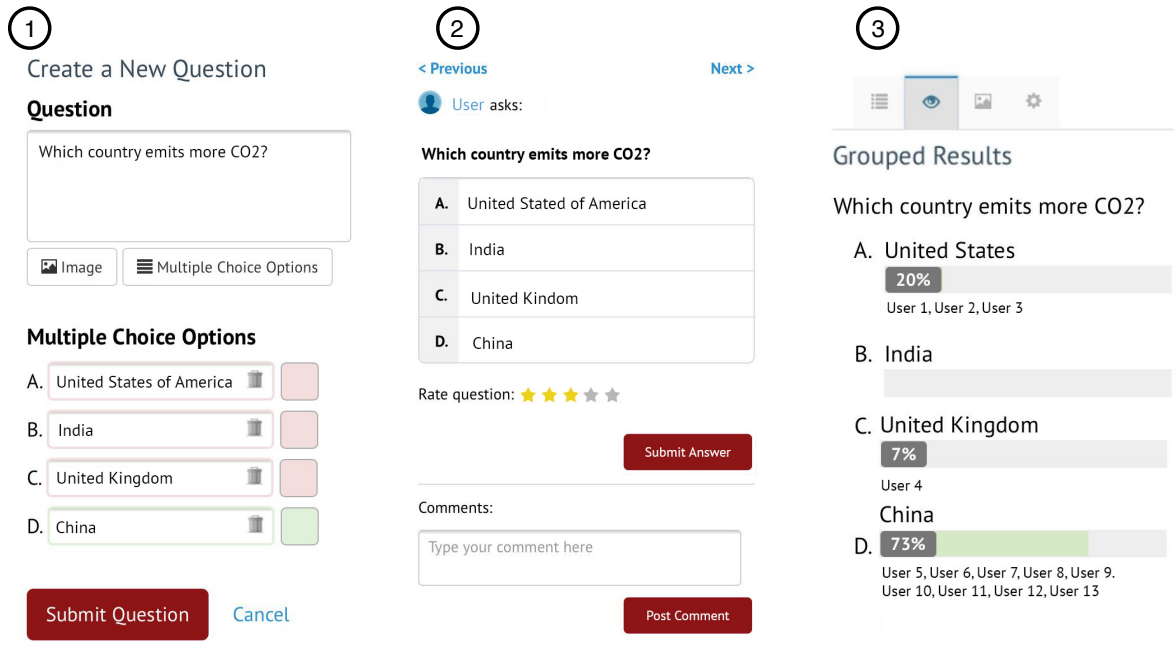

Figure 2. Schematic view of the SMILE user interface.

At the beginning of each SMILE session, students need to log into the SMILE application on their mobile devices or laptop and join a group assigned by the teacher. Once the teacher starts the SMILE session, everyone is automatically in the “create” mode. In this mode, students need to create questions and submit them to the system. The interface presents a box where students need to fill in their questions (Figure 2/Step 1). Below the creation box, there is the option of adding pictures or videos to the question and also an option of adding multiple choice answers. At the bottom of the screen, there is a red button on which they need to click in order to submit their questions to the entire group. Afterwards, a new question can be created.

After all the students have submitted their questions, the teacher enables the “solve” phase, and students can solve the questions created by their peers (Figure 2/Step 2). For open-ended questions, students see the question and a box below it where they have to fill in their answer. For multiple choice questions, students can see the question and a set of multiple choice options. They can click on the correct option. In order to validate their answers, they need to click on the red button on the bottom of the screen that says, “submit answer”. They can also leave comments on the questions. Below the answers, there is a five-star icon, which students can use to classify the quality of the question on a five-point scale ranging from 1 star (not good) to 5 stars (excellent). To answer the next question, they need to click on the button “next” on the top right corner of the screen.

When all the participants are done answering and rating the questions, the third phase begins. In this phase, every student can see a summary of the session’s results, and the teacher encourages the students to reflect on each other’s questions and answers (Figure 2/Step 3). They can also see which questions they have answered correctly or incorrectly, as well as which questions have received the highest ratings.

The entire process is monitored by the teacher via SMILE on a special interface for the session leaders. All the questions created by the students are stored in the system. Recently, the SMILE server has become accessible in the cloud at www.smile.stanford.edu.

The SMILE server software enables participants to generate questions in both public and private groups for all participants to share, solve, evaluate, and discuss questions. In places where there is no or limited Wi-Fi connection, SMILE can be used via SMILE Plug, which provides a local Wi-Fi point. Thus, the mobile devices of teachers and students will be connected to each other and to the Plug. The SMILE Plug is equipped with various educational open-source programs, such as KIWIX (a mobile version of Wikipedia) and Khan Academy Lite. Recently, the SMILE Plug was implemented using a Raspberry Pi 3. This solution is especially useful in areas with limited electricity, since the Plug can be charged by being plugged into a power bank.

2. Case Description

As the main focus of this study is on children from underserved communities in developing countries, part of the evaluation phase of this study was carried out in an indigenous village located in the south of the Brazilian Amazon. In the following lines, a brief overview of the context where these students live will be given in order to enhance the comprehension of the difficulties they may encounter in using an inquiry-based mobile learning technology. The village is located in the Xingu Indigenous Territory (TIX). It is estimated that 262 people (ISA, 2017) live together in this village, relying mainly on natural resources (fish and crops) and occasional craftwork sales to survive. Climate change has been substantially affecting the region and impacting the life of its inhabitants. The increased temperatures and changing rain patterns are affecting the region's forests, water availability, biodiversity, agriculture, and human health (WWF, 2017). Most of their reservation lands (2.642 hectares) remain preserved, but the reservation is now "a green island surrounded by a large deforested area" (Baruzzi, 2007, p.182).

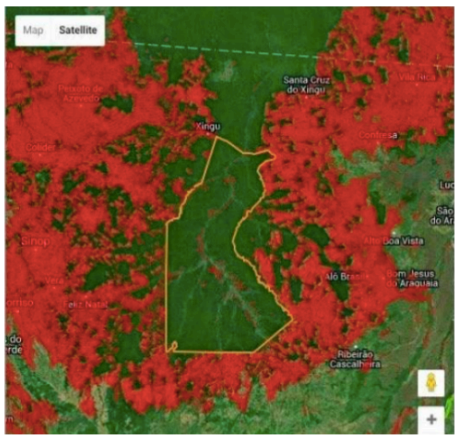

Figure 3 (left). Crops in the limits of the Xingu reservation/Google Images.
Figure 4 (right). The reservation is named the "Green Island" due to deforestation in its surroundings/ ISA, 2016.

The village is relatively remote, located around 8 hours (access by boat and truck or small plane) from the closest city, Canarana, State of Mato Grosso, Brazil. The villagers maintain their native traditions such as kinship rules for relationship, puberty reclusion, and mourning rituals. The village is organized in a circular form, with 12 big communal houses covered with thatch and built in an oval shape and a courtyard in the middle, considered as the political site of the village and where the men's house is located and the political decisions are made.

The other houses are inhabited by extended families, composed by relatives linked by different kinship and generations. The houses have two small doors, one leading to the courtyard/center of the village and another leading to the back. There are no divisions in the inner space of the houses, except the cabinets where the adolescents in pubertal reclusion, the couples with newborn children, and the widowers in the period of mourning have to stay. Everybody sleeps in hammocks. In the center of each house, next to the back door, there is a communal fire for making beju (a fried flat bread made of cassava flour) and fish. The water is stored in large pots inside the house. There is no electricity, filtered water, or sanitation system in the village.

Since 2008, there is a public school in the village, run by the State of Mato Grosso, where the children attend classes in their native languages and in Portuguese. The school has 40 students enrolled, from 6 to 14 years old, divided into four groups/classes composed by around 10 students per class. Every group has an average of two and a half hours of classes a day, mainly related to literacy (Portuguese) and numeracy. The school has four teachers, who are locals and studied previously in the same school. They have teacher training once a year.

Close to the school, there is a Public Wi-Fi location where they have three desktop computers powered by solar energy and public Wi-Fi via a direct satellite connection. Some of the villagers own mobile phones and often use them to contact their relatives and friends living in other villages or in the city. Since there is no phone network available in the village, they use the mobile phones through the Wi-Fi connection.

Figure 5. Schematic overview of the main sites of the village.

3. Theoretical Framework

3.1 Bloom and the Path to Critical Thinking

Critical thinking is known as the cognitive ability to comprehend a phenomenon holistically (Paul, 1992) by carefully evaluating evidences, making inferences, and considering own personal bias in order to solve problems. Critical thinking is widely recognized as one of the essential skills for the 21st century (Lai, 2011). However, many scholars have reported an insufficiency of critical thinking in the population (Halpern, 1998; Van Gelder, 2005). This gap is suggested to be related to the lack of educational experiences that encourage critical thinking in students (Paul, 1992).

In order to stimulate critical thinking, in 1956, the American psychologist Benjamin Samuel Bloom and his associates created a taxonomy of thinking constituents, named Taxonomy of Educational Objectives, known as Bloom's Taxonomy (Bloom, 1956). The taxonomy provides a schema of a six-level classification system, aimed at standardizing learning goals and engaging students in higher-order thinking processes from a lower to a higher level. The taxonomy became a practical educational tool, widely used and known as one of the major contributions to educators who look to stimulate higher-order thinking in students (Conklin, 2005).

The basis of Bloom's Taxonomy is found in the work of the German psychologist and philosopher Johann Friedrich Herbart (1776-1884), considered as one of the founders of modern pedagogy and education theory, who developed a five-step model of teaching which includes Preparation, Presentation, Association, Generalization, and Application. Bloom's six-level taxonomy (Table 1) was based on distinctions teachers have been observing in students' thinking behaviors (Bloom, 1956). Each level of Bloom's taxonomy requires more complex thinking than its predecessor and encompasses a list of verbs, which express actions to be taken in order to reach the competencies required to pass to the next level (Ferraz, 2008).

The first level, knowledge, simply requires recall of information; the second, comprehension, requires the interpretation of information; the third, application, requires the application of knowledge to solve problems; the fourth, analysis, demands the division of a learned concept into smaller parts on which the concept is based; the fifth, synthesis, requires the combination of the different parts to form a new concept; and the sixth, evaluation, which is the highest level, requires the judgment of information for a given purpose based on evidence and criteria.

Bloom's taxonomy has been applied in traditional classrooms to encourage students to think critically and develop cognitive levels of superior thinking (Anderson & Krathworthl, 2001). This is done through the elaboration of instructions and training based on a conjunction of "lower-order cognitive processes," which require basic comprehension and recall, as well as "higher-order cognitive processes," which require higher levels of inferences, analysis, evaluation, and synthesis, distinguished as High Order questions and Low Order questions (Swart, 2010). In this sense, questions and debates are central elements of the promotion of critical thinking (Marquardt, 2011). Thus, a questioning culture promotes student learning, optimizing problem identification, problem solving, and critical thinking skills.

Table 1
Bloom's taxonomy with synonyms and illustrative verbs

Level	Objective	Definition	Synonyms	Illustrative verbs	Classification
6	Evaluation	Judging the value of the system based on given criteria	Estimate Assessment	Justify; conclude; evaluate; verify; confirm; determine; analyze	HOq
5	Synthesis	Putting together elements/parts to form a system	Combination Fusion Creation	Generate; combine; construct; formulate; propose; assemble; design; predict; improve	HOq
4	Analysis	Breakdown of a system into its elements/parts	Study Scrutiny Breakdown	Distinguish; compare; contrast; differentiate; classify; categorize	HOq
3	Application	The use of abstractions in particular and concrete situations	Use Purpose Appliance	Change; demonstrate; modify; solve; use; show; calculate	HOq
2	Comprehension	Translation, interpretation and extrapolation of elements/parts	Understanding Grasp	Explain; convert; estimate; rearrange; summarize; derive; review; relate	LOq
1	Knowledge	Recall or recognition of specific elements/parts	Information Facts Data	Name; list; state; define; describe; label; sketch; discuss; identify; select; insert; complete;	LOq

Retrieved from Swart (2010).

3.2 Inquiry-Based Learning Technologies

In the core of the critical thinking process is the ability to inquire and question any given piece of information. The questioning process is also in the basis of the inquiry-based learning (IBL) model (Becker, 2000). In this model, "students learn about inquiry and learn through inquiry, and develop their higher-order thinking skills and self-directed learning skills". (Lim, 2004, p.628). Thus, by asking questions, answering, sharing and reflecting, students stalemate their cognitive skills, including their capacity to structure their way of thinking, to evaluate sources, and to keep track of their own learning. In sum, questioning assists students in developing a problem and searching for possible explanations related to that (Olson & Loucks-Horsley, 2000).

Technology-integrated IBL online environments have also been reported as an effective tool to provide opportunities for enhancing students' critical thinking (Ucar and Trundle, 2011). Many studies have indicated positive impacts of the technology-integrated IBL environment on learning effectiveness (Buckener & Kim, 2014; Hwang, Tsai, et al., 2012, Shih, 2010). However, since "low levels of self-regulation are particularly apparent in inquiry

learning" (Manlove, Lazonder, & de Jong, 2006, p.106) the major challenge of IBL online environments is "how to support learners in a way to improve inquiry during their learning process" (Lim, 2004, p.637). To better support technology-integrated IBL practices, previous studies have advocated the incorporation of instructional features in these technologies, like goal-lists, templates, hints, cues, and prompts, as a supporting tool to drive students' cognitive processes and help them to engage in progressive critical thinking (Lakkala, Lallimo & Hakkarainen, 2005; Li & Lim, 2008; Manlove, Lazonder, & de Jong, 2009).

Several researchers, with students of different ages, have indicated the positive effects of regulatory scaffolds[3] on students' learning. For example, by testing self-monitoring and self-efficacy prompts in a Webquest environment among college students, Kauffman (2004) found that students provided with prompts surpassed the students who were in the control group (without prompt) in posttest. Similarly, results from a study conducted by Manlove, Lazonder, and de Jong (2006) among high school students revealed that students in the experimental condition, who received regulatory support tools such as hints, goal hierarchies, and not taking facilities, performed better than students in the control condition, who used a non-supported version.

Finally, the results of the study by Kramarski and Gutman (2006) with ninth grade students in a mathematics e-learning environment indicated that those who received questions to enhance regulation and metacognition in solving transfer problems and mathematical explication performed better in the posttest when compared to the students in the control group. Although, the results of using regulatory instruments seem promising.

3.3 Usability for Mobile Learning

Mobile devices have been progressively integrated into a range of areas, becoming indispensable to the execution of many core activities of the 21st century. One of these areas is education. Mobile learning is one of the current trends in education, and mobile devices have been utilized as a learning platform for students and teachers from all over the world (Wang & Dey, 2013). Mobile learning takes place when the student is not at a fixed place or when the student benefits from learning opportunities provided by mobile technologies. Thus, mobile learning aims to engage students in educational activities featuring mobile technologies as a mediating tool for learning.

Due to recent improvements in Information and Communication Technologies (ICTs), mobile devices have become more affordable, highly portable, and widely available (Kim et al., 2011; Wu et al., 2012). These evolutions have encouraged researchers to take a pedagogical look toward the development of educational applications for mobile devices (Ali et al., 2015). The specificities of mobile devices, however, such as screen size, resolution, mobility, and connectivity, restrict the display of content and require complex user interfaces (Wang & Dey, 2013). Consequently, a range of studies has tried to improve the usability of mobile learning applications in order to guarantee the development of user-friendly technologies (Black & Edgar, 2009; Kukulska-Hulme, 2005; Kukulska-Hulme & Traxler 2007).

---

[3] The term scaffold refers to a variety of instructional techniques used to move students progressively toward stronger understanding and, ultimately, greater independence in the learning process (The Glossary of Educational Reform, available at http://edglossary.org/scaffolding/)

In the last decades, usability has been at the core of the debate among different professionals whose goal it is to develop user-friendly technologies. It is defined by the International Organization for Standardization (1994) as the extent to which a product can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a certain context of use (ISO 9241-1). Consequently, a product with a high usability should include the following three criteria: Effectiveness: the accuracy and completeness with which users achieve specified goals; Efficiency: the effort of achieving results of certain accuracy and completeness; and, Satisfaction: which is the freedom from discomfort and positive attitudes towards the use of the product.

A broader definition of usability adds three other criteria besides effectiveness and efficiency. Quesenbery (2003) proposes that a product with a high level of usability should also be engaging, error tolerant, and easy to learn. Engagement is related to satisfaction and it means how well the interface draws the user into the interaction and how pleasant it is to use. Error tolerance is related to how well the product is able to prevent users from making errors and helping users to recover from mistakes. Lastly, easy to learn means how well the product supports both the initial orientation and the learning continuation throughout the complete lifetime of the use of the product. This definition broadens the concept of usability, emphasizing that the users should also be able to have a nice experience.

These usability guidelines are general and mostly have been developed and tested for creating desktop learning applications (Raza, Capretz & Ahmed, 2012). Although the general usability principles can also be applied for mobile learning, it has been less extensively covered in the academic literature, leading to a lack of usability studies featuring the specificities of this sort of applications, such as mobility, screen size, and connectivity (Ali et al., 2015; Traxler & Leach, 2006). Less is known about the usability of mobile learning applications aimed at improving the education in underserved communities, where end-users possess low literacy levels and whose exposure to technology is low.

Although several studies have demonstrated the capacities of mobile learning applications to widen access and supplement education in remote and under-served areas of the world (Attewell, 2005, Kim et al., 2009; Ramos, 2015, Zurita & Nussbaum, 2004), one of the main challenges of mobile learning programs is still to guarantee that low-literate individuals will be able to optimally use these technologies.

Properly integrating mobile learning applications into classrooms of underserved communities has also been reported to be problematic (Warschauer & Ames, 2010). The problems include specific support, infrastructure, and particularly, teacher training (Kim et al., 2012; Rusten, 2003). In remote villages of underdeveloped regions, teachers have very little experience with ICTs, and often, the speed with which children are adopting new technologies is higher than the teachers' (Kim et al., 2012). In these contexts, it is important to ensure that the mobile learning technologies implemented in schools of underserved communities present a high level of usability to guarantee that these children will be able to make an optimal use of them.

4. Exploring SMILE (Phase I)

The research started with an exploratory study on SMILE. The main goal was to find the main problems that were faced by children from underserved communities when using this technology. From March 20 to 27, 2017, the researcher visited the Office of Innovation and Technology at Stanford University in California (USA) where SMILE was developed. Three semi-structured interviews were conducted with specialists who have been implementing SMILE with children of underserved communities. The locations include India, Nepal, South Africa, Indonesia, Ghana, and Tanzania. Besides these locations, one of the interviewed professionals was also implementing SMILE in a school located in the USA with first graders (students of 5 and 6 years old) and shared the difficulties faced by them during the interview.

The interviews covered two main topics: the most common problems and challenges they noticed these students faced when using SMILE, and possible solutions: what do they think could be added or changed to SMILE in order to guarantee that these students would make an optimal use of it? The interviews took around 20-30 minutes. They were recorded, transcribed, and the findings are described below.

4.1 Challenges

The challenges ranged from problems related to digital skills, the interface of SMILE, and more complex issues, such as difficulties in creating a question and critical thinking. Additionally, the issues pointed out by the professionals also highlighted the difficulties faced by local teachers in these communities.

One of the problems indicated by the three professionals was the children's lack of familiarity with the keyboard. *"They didn't know what the space bar was. You see them typing but it is a one huge word, so we had to explain to them that they have to put the space between the words,"* one professional explained. Another professional said: *"I had to teach them how to capitalize a letter, how do you use a back space to erase something. But they learned really fast."*

Another problem mentioned was students' lack of familiarity with a digital application interface. *"They were not familiar with how an interface works, like knowing that clicking on a button would lead you somewhere, it was something that was hard for them in the beginning. Sometimes we said click in [Join a Group], but then they would click around it but not in the actual button itself,"* explained the professionals. Similarly, they also mentioned problems particularly related to the SMILE interface. *"Some students, when they tried to submit their question, they were clicking on the button that says [attach media] thinking it was for submitting their question because it was right underneath the box that says create your question."*

Rating each other's questions was also reported to be a challenge according to the professionals. *"It was a little confusing for some students because now they have to answer a question and rate it at the same time, and I think it is too much for them"* (See Figure 2, Step 2). *"Some children always rate their peers' questions on five stars, it was hard for them to understand what a good question really is and rate them. Also for the comments they can make when rating the questions... they are mostly compliments and not really critical."*

This first mention of critical thinking highlighted another dimension of problems that goes beyond digital skills, such as creating a critical question. "*Making their own questions is something that most of them have never done before. So, it is a whole new experience and they have a lot of difficulties. Most of them are just used to memorize and solve questions, but getting them to create questions is a whole new thing, and this is a big challenge. Also, in some of their cultures, they are not taught and encouraged to ask questions,"* one professional explained.

They also described the discomfort of some children when they were asked to create a question with SMILE for the first time. *"The creating question phase, I think this is the hardest part of SMILE, because when you create a question, it is sort of a blank screen. There is a box that says, [tap your question here] and it is a little scary to them. And for the kids, they are so used to being told of what to do, and then you put a blank screen for them to create a question. Some of the kids had good response to that, but most of them had no idea what to do."*

Another interview explained the challenge with the multiple-choice options within the domain of creating a question. *"They don't have a good sense of the format of questioning, or an understanding the multiple-choice options. At the beginning, I had children that were making questions and as the multiple-choice answers they were also making questions because they didn't know the difference. Also, some of them made one really obvious multiple-choice answer and three other options completely unrelated"*.

They also highlighted that, besides creating a question, creating a critical question was a greater challenge. *"Critical thinking is something they are not used to. It was hard for them to understand what was a critical question (…) teaching them how to make good questions is a very long-term process,"* they explained. Also, for the teachers, teaching students to create critical questions was a challenge. *"Although they are supposed to be able to teach critical thinking, they can't because they have never learn about critical thinking, so they usually have a hard time when teaching with SMILE."*

They also pointed to the fact that the power of SMILE as a critical thinking enabler relies on a greater extent of skills of the teacher. *"Because there is no content built into SMILE, when you get it fresh, it is really based on the facilitator and how they want the students to use it. Although this is a student based technology, you need to have a good facilitator that can go around and review the questions with them, talk about good questions and bad questions, because without doing it, it is basically just the act of creating questions. Next week, more questions, done."*

This highlights a series of problems in the implementation of SMILE and sustainability in these locations. *"Some teachers also use it to digitalize their exams. It is ok if they do that, but it is better if they use it to teach how to create engaging questions, more than just simple answering the teacher's exam. Dealing with critical thinking is something hard and SMILE means a lot of work for the teachers. And most of teachers want an easy convenient way of teaching so they don't have problems to worry about. So, this is a big challenge,"* they explained.

Based on these issues, in the following lines, the question of how to make SMILE more usable for students and teachers in these contexts is addressed.

In sum, the key issues with the basic version of SMILE is the user interface. Children are not comfortable enough to use a keyboard as input. Also, they are not used to classic digital user interfaces. This contributes to the problem that children have trouble creating

questions and the multiple-choice format. More specifically, creating critical questions is even harder due to the limited knowledge on how to create this and the lack of usability in the digital user interface.

4.2 Possible Solutions

In terms of digital skills-related problems, such as the children's lack of familiarity with the keyboard, one of the professionals suggested the incorporation of a verbal input. *"Since they have a hard time typing, maybe it would be nice to have a verbal input, so they could ask the question orally, on voice, and the system would capture. So, anyone, even without literacy, could still participate."*

For the problem related to their lack of familiarity with a mobile learning application interface, one of the professionals suggested: *"I think we could think about a progress track, for example, in which phase I am, what question I am on, and how many questions I still to answer. I think it would make it easier for them to understand the entire process."* Specifically for the error on which button to click in order to submit their questions and the uncertainty whether they have submitted their questions or not, the following solution was proposed: *"We have already changed the placement of the submission button to avoid the error, but we could also add something like 'you have submitted your question, create a new question."*

For the rating of the questions, the following improvement was proposed: "*I think if we had the students to answer the questions first and do not worry about rating, and then after they answered all the questions, then would get an overview of all the questions and could rate them comparing all questions, and not just based on one. I think the best thing is to move it to a separate session, after they have answered all the questions."*

For the creation of questions, critical thinking, and teacher support, the following solutions were proposed:

One of the professionals suggested the use of examples of questions within the software. *"Because usually the trainings in these regions are conducted within a few weeks, making something in the technology that gives the teachers some help would be nice. Like giving some examples of questions they can use with the children. It would make it a lot easier for the teachers and students to use it. Otherwise, it is just a plain text box."*

The idea was further developed as the beginning of questions to be incorporated into SMILE. *"One of the ideas we had was to create a little prompter, like 'this is a question starter'. For example, "What is the color of …", and then students could copy that and complement with their own ideas. Something simple that hopefully won't add so much confusion to them. Sort of giving them a guide, question prompters that helps them to create questions."*

Similarly, another professional mentioned the strategy of the question starters on paper as a successful practice. *"In my class, we have a desk in the corner of my classroom and they have sentence strips that shows beginnings of different kind of questions and based on that they can think how to structure their sentences - we call them golden questions. So, sometimes I ask the children to go to the golden desk and pick a random strip, and based on that, I ask them to create their own questions with this beginning. So it kind exposes them to high quality questions, so that's was a good way to show them how good questions are structured."*

Another idea was to incorporate a game feature able to familiarize the children with the questioning process. *“I thought about something for the students to play… sort of a game in which they could become familiarized with the questioning process. When you add something like a game, they feel like it is something they are familiar with, and while they are playing the game, they are actually learning how to make critical questions.”*

Also, there was the idea of the incorporation of a framework able to gradually improve their questions creation and critical thinking processes. *“Make the software like, the harder you progress, harder the questions you make. So, after you master the first level questions you get to another level of complexity. So, I think this is an area we can improve. Not overloading them, but giving them a pathway.”*

In sum, there were a lot of suggestions to improve the user interface. Though, the key points for improving the quality of the questions all came down to either giving examples of questions or the idea of question prompters. All of the challenges and solutions mentioned and proposed by the professionals formed the basis for the development of a prototype aimed at children of underserved communities.

5. The Puzzle Model (Phase II)

The combination of the findings of the theoretical framework and the conclusions drawn in the previous chapter lead to the development of a new feature of SMILE based on the following characteristics: (1) presence of the model of questions, particularly question starters, which should be developed according to (2) a critical thinking framework able to give teachers and students a path to gradually improve their question creation process and, (3) with characteristics of games (puzzle).

The Puzzle Model consists of question starters corresponding to Bloom's six levels: (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis and, (6) evaluation. Each level has a cognitive thinking objective highlighted in Table 1 (see the Theoretical Framework). In total, 30 different question starters (five per level) were designed to guide the students' inquiry activities with SMILE (Appendix 1).

The Puzzle Model was designed in collaboration with a web-developer from the Office of Innovation and Technology, from Stanford University. From May to June 2017, all the specificities of the new feature were created, tested, translated to English, Dutch, and Portuguese (Appendix 1), and incorporated into the basic SMILE version. All the procedures of the design were made online in a specific testing domain where the researcher and the web-developer could do tests and implement changes.

As explained, the Puzzle Model was integrated within the SMILE system (testing version) together with other new features (prompts, rubrics, and hidden mode). All of them are aimed at helping users to create high-quality inquiries. When the teacher creates a new activity, the system provided them with an overview of the activity settings, including the new features (Figure 6). The Puzzle Model was placed on the right bottom of the screen and gave the option to the teachers to enable or disable it, as well as to choose which level of Bloom they were going to set for an activity.

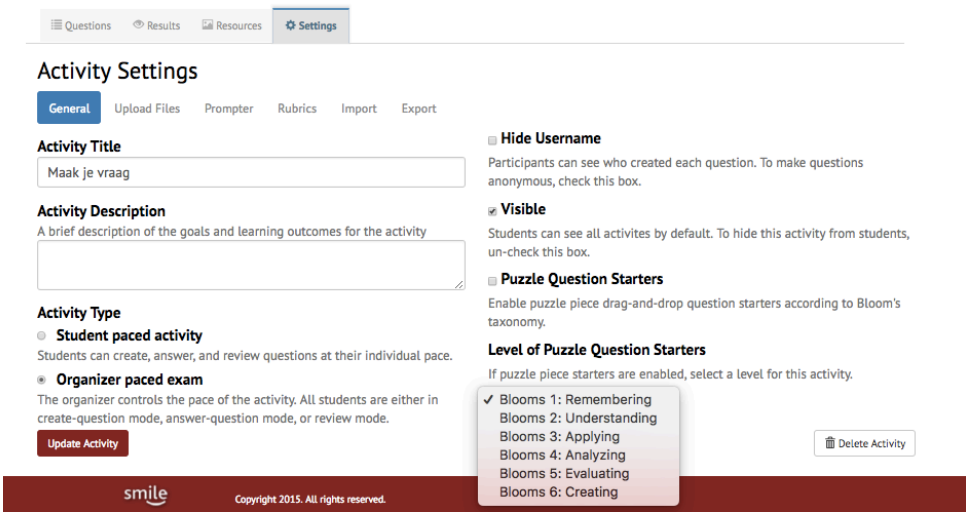

Figure 6. SMILE settings with the Puzzle Model options.

The Puzzle Model required the addition of another box (blue) to SMILE's original interface (Figure 7). The question starters were placed in the blue box in the form of "puzzle pieces," as demonstrated in Figure 7. In order to formulate a question, students need to drag

down each puzzle piece to the second line of the blue box. Once a piece is dragged to its correspondent place in the second line, its corresponding word is automatically displayed in the blank box. Thus, once students have dragged down all the pieces to the second line, they form the beginning of a question in the blank box. From the example, the question starter could be: “What are the consequences of…?” Subsequently, students need to complete the end of the question with their own words.

Additionally, the model aims at teaching students how to formulate an inquiry. They were not allowed to place the puzzle pieces in the wrong order, for example. If they select the piece [WHAT], they are only able to place this piece in the beginning of the second row and not at the end. Thus, every piece has a pre-established intended place in the model.

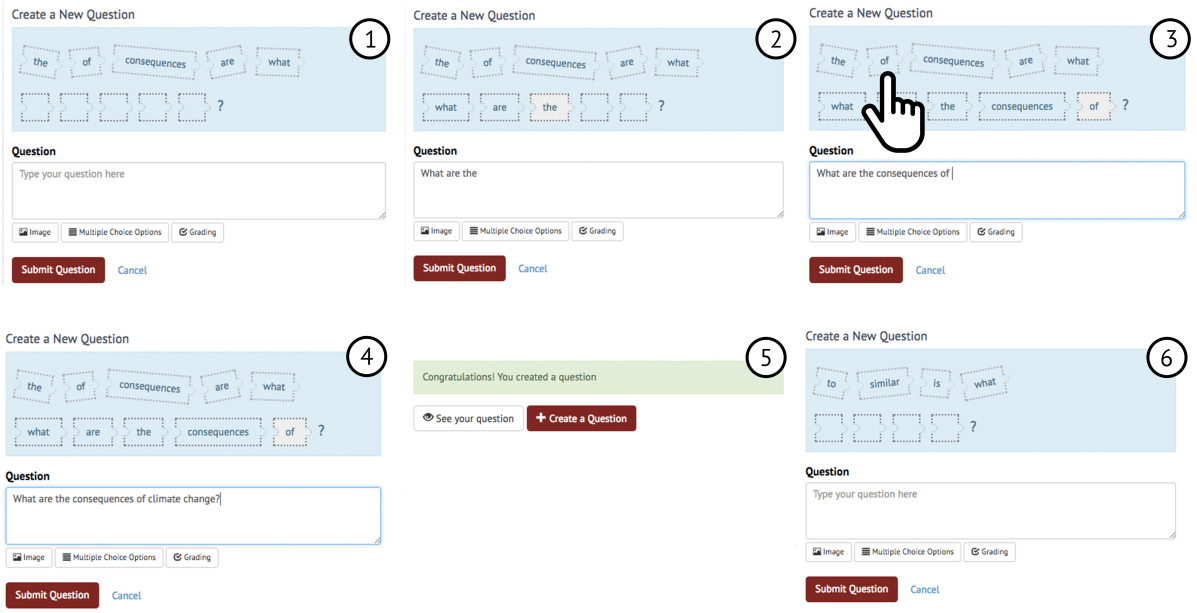

Figure 7. Schematic view of function of the Puzzle Model.

Based on this puzzle model (Figure 7) a student could create a question like “What + are + the + consequences + of + climate change?” After students submit a question, they are redirected to a new screen giving them confirmation that they have created the question: “Congratulations, you have created a question. Click to create a new question” (Figure 7, step 5). This is also one of the new features of this study.

At this screen, students can click on “create a new question” and they will receive a new “puzzle” with a similar model of a question from the same Bloom level (Figure 7/Step 6). The question starters are randomized, so a user does not get the same one twice. After a student has created 5 questions of the same Bloom level, the system redirects them to the basic version of creating questions with SMILE (i.e. without puzzle pieces). Teachers can upgrade the level of the Puzzle Model anytime by choosing a new level in the settings of each activity (Figure 6).

The choice of designing question starters in different Bloom levels was made in order to give students a procedural facilitation aimed at structuring their cognitive thinking towards the level of the question they are trying to formulate.

6. Usability Evaluation (Phase III)

In this phase of the study, a summative evaluation was conducted to assess the usability of the new feature of SMILE in comparison with its current version and whether it differs among students from different locations.

6.1 Method

A usability evaluation model was developed based on the definition of ISO 9241-11 (International Standards Organization, 1994), which proposes the assessment of usability by its three sub-constructs: effectiveness, efficiency, and satisfaction. The evaluation model comprises a multi-methodology perspective in which both quantitative and qualitative approaches are integrated. First, a formal experiment was administered in two schools, comprising a lecture about a chosen topic, which will be further explained in the procedure. One school is located in the Netherlands and one in an indigenous village in the Amazon. Students of both schools were asked to create questions using SMILE, some using the Puzzle Model and others without it. The experiment was conducted in order to gather statistical data regarding the effectiveness and efficiency of the Puzzle Model on assisting students in creating questions. Subsequently, a focus group was administered in order to gather qualitative data from the students' responses related to their satisfaction in both conditions.

6.1.1 Variables

The evaluation model comprises two independent variables (intervention and location) and one dependent variable (usability). The first independent variable is *intervention* and its two sub-levels, (1) the presence of the Puzzle Model or (2) its absence. The second independent variable is the students' *location* and its two sub-levels, (1) the Netherlands or (2) the Brazilian Amazon. The dependent variable, usability, comprises three sub-levels (1) effectiveness, (2) efficiency and, (3) satisfaction. Following the work of Frøkjær, Hertzum and Hornbæk (2000), the summative evaluation experiment focused on two sub-levels of usability: effectiveness and efficiency, while satisfaction was examined at the end of the experiment via focus groups.

Effectiveness, which is *"*the accuracy and completeness with which users achieve certain goals*"* (Frøkjær, Hertzum & Hornbæk, 2000, p. 345), was measured by the quality of the created questions, indicated by the level of Bloom's taxonomy (Bloom, 1956). From Knowledge (L1), being the lowest level, to Evaluation (L6), being the highest level (see Theoretical Framework, Table 1). The questions created by students were recorded via the SMILE system, exported, translated to English, analyzed, and categorized corresponding to one of the six levels (Appendix 2). For example, to be categorized as belonging to one of the following levels, a question must mainly express: recall of information (level 1), interpretation of information (level 2), application of knowledge (level 3), analysis of different information (level 4), synthesis of different information and suggestion of new concept(s) (level 5), and the judgment of information for a given purpose based on evidence and criteria (level 6).

Afterwards, the questions were categorized as either being higher-order questions (HOqs) or lower-order questions (LOqs), following the classification established by Swart (2010), theoretically based on the levels of Bloom's taxonomy (see Theoretical Framework, Table 1). This classification assumes that questions from levels 1 and 2 are LOqs since they merely rely on recall or explanation of information. On the other hand, questions from levels 3, 4, 5, and 6 are considered HOqs since they express elements of critical thinking. Thus, in this study, questions from levels 1 and 2 were classified as LOqs while questions from levels 3, 4, 5, and 6 were classified as HOqs.

Efficiency, which is "the relation between (1) the accuracy and completeness with which users achieve certain goals and (2) the resources expended in achieving them" (Frøkjær, Hertzum & Hornbæk, 2000, p. 345), was measured by the number of questions students created within a given amount of time (within 10 minutes). Lastly, Satisfaction, which is "users' comfort with and positive attitudes towards the use of the system" (Frøkjær, Hertzum & Hornbæk, 2000, p. 345) was assessed by the students' comments on the focus group interview, conducted after the experiment. Responses of the students in all the groups were analyzed to detect the patterns across the groups.

6.1.2 Hypotheses

Based on the research findings and above-mentioned considerations, the following sub-questions and hypotheses were created in order to answer the main research question aligned with the research goal:

Research questions:

Taking into account children from the Amazon and students from the Netherlands:

1. To what extent is the Puzzle Model usable for these students?
1a. Is the Puzzle Model effective for them?
1b. Is the Puzzle Model efficient for them?
1c. Are these students satisfied with it?

The following are the hypotheses:

Effectiveness
H1a - the students in the experimental group create more High Order questions than the students in the control group.
H1b - the students from the Netherlands create more High Order questions than the students from the Amazon.

Efficiency
H2a - the students in the experimental group create more questions than the students in the control group.
H2b - the students from the Netherlands create more questions than the students from the Amazon.

Satisfaction

No hypotheses were formulated relating to satisfaction since no quantitative method was used to measure it. Thus, based on the students' comments on the focus groups, the research question about satisfaction will be answered.

6.1.3 Study Design

A 2x2 study design was formulated (Table 2) with the goal of assessing the effectiveness and efficiency of the Puzzle Model for students of both locations. Students from two schools, one from the Netherlands and one from the Amazon/Brazil, were assigned to one of the two conditions: experimental (using the Puzzle Model) and control (not using the Puzzle Model). Satisfaction was further examined based on the students' responses during the focus groups after the experiment.

Table 2

Different variables of the research

Independant	**Dependant**
Intervention	Usability
Presence of puzzle model (experimental)	Effectiveness
Absence of puzzle model (control)	Efficiency
	Satisfaction
Location	
The Netherlands	
The Brazilian Amazon	

6.1.4 Participants

A total of 40 students from two schools were selected to participate in the study. One school was located in a medium-size city in the central-eastern area of the Netherlands, and another school was located in the Xingu Indigenous Reservation, in the southern part of the Amazon Rainforest in Brazil.

The class at the Dutch school was composed of 22 children from 8 to 9 years old. These students were from an urban area in Europe. They had access to educational materials and technologies from an early age, both at home and at school. They were alphabetized in Dutch, but also took English classes from the age of six as part of their curriculum. In the school where the experiment took place, students had an average of 5 hours of classes per day. ICTs were used by teachers and students on a daily basis and were integrated into the classes.

The group of students from Brazil was composed of 18 children ranging from 10 to 13 years old. Although the initial idea was to conduct the experiment with students of the same age in both locations, this was not possible due to the insufficient literacy levels of the students from the Amazon who had the same age of the students from the Netherlands (i.e. 8-9 years old). Hence, the subsequent higher class was selected.

These students were from a rural and remote area in Latin America, and lived in an indigenous village located in the south of the Brazilian Amazon. The native community

Figure 8 (left). Paper and pencils were the tools used by the students from the indigenous school in Brazil. No ICTs were used before this study.
Figure 9 (right). ICTs are integrated to the classes in the Dutch School and used daily by students and teachers.

where they live mainly survives on fishing, agriculture, the occasional handicraft sale, and social welfare programs (such as Zero Hunger[4]). Originally, their native dialects didn't have a written alphabet. By the age of 6 years old, the children start attending the school and are alphabetized in Portuguese, although they already speak native dialects. They have an average of 2 hours of classes per day. Educational resources are very scarce, only the teacher has a book on which the activities are based. Usually, the teacher writes the activities on the blackboard and asks the children to copy it in their notebooks. ICTs, such as mobile technologies, are not part of their educational experience.

Table 3
Context of the study sites

Location	Urbanicity	Economic developmen t level	Age	Grade	Use of ICT's at school	World Region
Xingu Ingenous Territory, Brazil	Rural	Low income	10-13	5th and 6th (one class)	No	Latin America
Oldenzaal, the Netherlands	Urban	Developed	8-9	3rd	Yes	Europe

6.1.5 Procedure

There were two moments of data collection. On June 23, 2017, the experiment was administered at the Dutch school in Oldenzaal. Later, on July 13, 2017, the experiment was administered at the indigenous school in Brazil. Prior to the experiment, the researcher met with each teacher of each location in order to familiarize them with SMILE and the content of a lecture on which the SMILE session was based in both schools.

[4] Povos Indígenas: um registro das ações de desenvolvimento social. Cadernos de Estudos Desenvolvimento Social em Debate. Ministério do Desenvolvimento Social e Combate à Fome. Governo Federal. Brasilia, 2008.

In both schools, the experiment took place within their normal school hours. The total length of the experiment ranged from 1h 20min to 1h 40min. The placement of the students into either of the groups was made by the local teachers. However, some students preferred to do the experiment in the first group and others in the latter group. Thus, the number of students in each group was not equal (Table 4). For the students in the Netherlands, an extra activity was arranged by the school, next to the experiment. The activity was unrelated to the experiment and its goal was to keep the other students busy while half of the class took part in the experiment. Hence, while the first group participated in the experiment, the second group participated in the extra activity and vice-versa.

For students from the Amazon, a concomitant activity was not possible. Thus, the local teacher asked the students who were placed in the second group to come to school 2 hours later than their normal time. Students from the first group went home after the experiment was done.

For the experiment, the researcher developed an introductory lecture through which students could exercise their critical thinking in both conditions (with and without the Puzzle Model). Since the background of the research is the use of ICTs for the achievement of the Sustainable Development Goals (ICT4D), one of its 17 goals was chosen to be the theme of the lecture. The lecture was based on issues related to climate change (Goal 13/climate action) supported by the content of the book “Help, My Igloo Melts" (Righton & Koene, 2010). This book tells stories from children, with a similar age to the students taking part in the experiment, who are suffering from the impacts of climate change, including one child from the Xingu Indigenous Territory. As a visual stimulus, a set of slides were designed by the researcher and used to support the lecture (Appendix 3).

The procedure was the same for all the groups in both schools. At the beginning of the experiment, the local teacher, with the help of the researcher, gave a lecture[5] of 15-20 minutes following the content of the book “Help, My Igloo Melts" (Righton & Koene, 2010). After the lecture, each student received a mobile device and was asked to log in to SMILE. The features of the tablets used by students in each location were similar (Quad Core, 7’, 8GB).

In the Dutch school, each student already had their tablet, provided by the school, with these specifications. For the Amazon, tablets with the same features were bought to equip the school. The only difference was that, in the Amazon, the tablets have an outside keyboard since the keyboard inside the screen might be too difficult for them.

After they had logged into SMILE, they were asked to answer 10 multiple choice questions related to the content of the lecture (Appendix 4). The questions were the same for all of the groups. Questions from 1 to 6 comprised additional facts about climate change in which students needed to guess the answer, such as “How many species are at risk of being extinct in the Amazon rainforest?” (A. 63 species; B. 633 species; C. 1633 species; or D. 2633 species). Questions from 7 to 10 were recall questions about the content of the lecture, for example, “Because of global warming, Jeremy's igloo melts faster.” (A. Yes; B. No).

The recall questions were used to assess whether students had the same level of comprehension regarding the lecture’s content. The results of the Two-Way ANOVA indicated that there was no significant differences among the groups on the mean scores in

[5] In the Netherlands, the lecture was given in Dutch. In Brazil, the lecture was given in Portuguese.

the recall test. No significant main effect was found of location $F(1, 36) = .000$, $p = .992$, neither for intervention $F(1, 36) = .022$, $p = .884$. Therefore, it was concluded that, prior to creating the question in each condition, the four groups did not differ on their knowledge of the content of the lecture.

Table 4
Groups distribution by location and condition

Location & Condition	Number of Students
The Netherlands	
Experimental	13
Control	9
Brazilian Amazon	
Experimental	10
Control	8

Besides checking whether all the groups had similar retention of the lecture's content, the goal of the activity was also to stimulate students' reflection on the discussed issues during the lecture, as well as to familiarize them with the SMILE interface. After they answered all the questions, a summary of all the results (generated via SMILE) were displayed on each mobile device and the teacher briefly discussed them. This part lasted for 15-20 minutes.

Table 5
Descriptive Statistics for Mean Score in the Recall Test

	Netherlands			Amazon			Total		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Control	2.44	0.882	9	2.50	0.922	8	2.47	0.874	17
Experimental	2.46	0.877	13	2.40	0.843	10	2.43	0.843	23
Total	2.45	0.858	22	2.44	0.856	18	2.45	0.846	40

Note. SD = standard deviation; N = number of students;

After the evaluation of the results, the students were asked to create their own questions (open-ended) on the content of the lecture using SMILE. The experimental group created questions using the Puzzle Model, which included "question starters" corresponding to the Application level[6]. The control group created questions using the basic SMILE version (i.e. freely, without any question starters).

The local teachers were advised to interact as much as possible with the students during this phase. Ten minutes after the start of the activity, the teacher asked them to stop creating questions and locked the SMILE session. Students were not aware that this activity

[6] See theoretical framework, Table 1.

would be stopped after 10 minutes. Right after the experiment, a focus group was conducted with each group in order to gain insights on the students' perceived satisfaction on creating questions in both conditions. Each session with a focus group lasted for about 15 minutes.

6.2 Results

6.2.1 Effectiveness

Effectiveness was measured by the quality of the created questions, indicated by their corresponding levels according to Bloom's taxonomy (Bloom, 1956). The results from the cross-tabulation (Table 6) show the distribution of the valid questions[7] created by experimental and control groups in each location according to the Bloom level they represent.

The experimental groups from both locations were induced to create questions corresponding to level 3, the first of the four levels considered to represent critical thinking. Level 3 is *application,* which refers to the ability to apply knowledge to an actual situation and suggest solutions for actual problems. Students working with the Puzzle Model received question starters from this level.

Table 6
Distribution of Questions Classified According to the Bloom's Level per Location and Condition

Groups	L1 Knowledge	L2. Comprehension	L3 Application	L4 Analysis	L5 Synthesis	L6 Evaluation	Total
Amazon							
Control	6	5	1	0	0	0	12
Experimental	0	4	18	2	1	0	25
The Netherlands							
Control	5	12	1	0	0	0	18
Experimental	1	7	26	10	1	0	45

The experimental group in the Amazon created 18 questions on the application level, which represent 72% of the created questions within the group (Figure 10), while the experimental group in the Netherlands created 26 questions on the same level, which represent 57.8% of the created questions within the group. Examples of created questions on the application level by students in the experimental groups include: "*What would you solve first to live well in the Amazon?*", "*What would you first change to the dirty factories?*", "*What would you do to end the drought?*"

Although the experimental groups received the Puzzle Model corresponding to the application level, and consequently, were induced to create questions on this level, they did not always do this. The experimental group of the Amazon, for example, created 4 questions (corresponding to 16% of the created questions within the group) on the comprehension level (L2), such as, *"How do you use an igloo?"* Conversely, this group also created 2

[7] Five questions were not considered as valid since three were out of context:(1) Wat zou je eerst oplossen aan de kleding; (2) Hoe gebruik je een klimaati? (3) iksnap het niet. Two questions were submitted without being completed, with only the puzzle model (4) What would you do; (5) What would you improve?.

questions on the analysis level (L4), such as, *"How do you use water to stop forest fires?"*, and 1 question on the synthesis level (L5): *"What would you do when there are no more fishes in the river?"*. No questions were created on the evaluation level (L6).

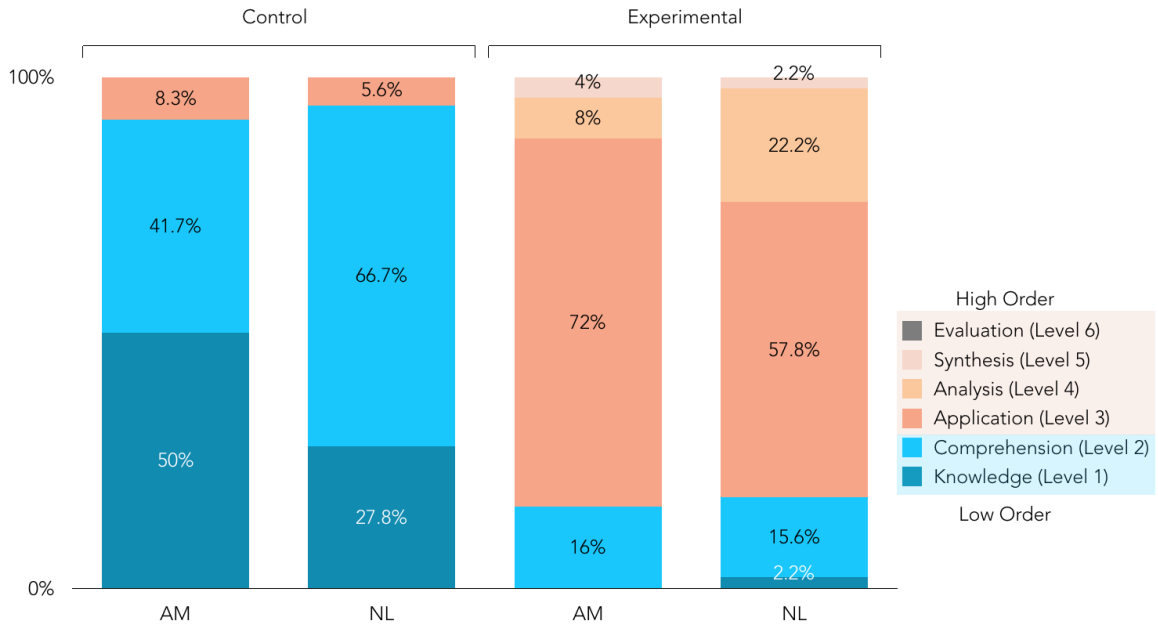

Figure 10. Percentage Within Groups of Questions Classified According to the Bloom's Level per Location and Condition

Similarly, the experimental group of the Netherlands also created questions both below and above the application level (L3). They created 1 question on the knowledge level (L1): *"Is climate change very bad?",* and 7 questions on the comprehension level (L2). For example, *"How do you use a spear?"* Conversely, this group also created 10 questions on the analysis (L4) level, such as, *"What would you first solve so that no trees are cut?"*, and 1 question on the synthesis level (L5): *"What would you do if the jungle was gone?"* No questions were created on the evaluation level (L6).

Different from the experimental groups, the control groups predominantly created questions on levels 1 and 2. The control group of the Amazon created 6 questions on the knowledge level (L1), and 5 questions on the comprehension level (L2), respectively. Only one question was created on level 3: *"How does the incendie burn the crops so fast?"* No questions were created on levels 4, 5, or 6.

A similar pattern was found in the control group of the Netherlands. This group created five questions on the knowledge level (L1), such as, *"How many people die in Ethiopia?",* and 12 questions on the knowledge level (L2), such as, *"Why does the ice melt so fast?"* Only one question was created on the application level (L3), for instance, *"How can Toey protect his harvest?"* Similar to the control group of the Amazon, no questions were created on levels 4, 5, or 6.

Figure 10 also shows that the patterns of question creation are similar in both locations. The right side of both histograms shows that, predominantly, the control groups of both locations created questions on the knowledge (L1) and comprehension (L2) levels, which are considered Low Order Questions (LOqs).

On the other hand, the right side of both histograms shows that the experimental groups in both locations created mostly questions on the application level (L3). Also, the experimental groups created many questions on higher levels than the application level (L3). For instance, questions on the analysis (L4) and synthesis (L5) levels, are considered High Order Questions (HOqs). These results suggest that the Puzzle Model might have been influencing the creation of HOqs for students of both locations.

In order to better comprehend the distribution of High Order Questions (HOqs) and Low Order Questions (LOqs) across the groups, a new variable was created, grouping the questions previously classified according to Bloom's levels within two categories: LOqs, uniting those questions of the levels 1 and 2 and, HOqs, gathering those questions of the levels 3, 4, 5, and 6.

The results from the cross-tabulation (Table 7) and the chart (Figure 11) indicate a significant pattern in the responses (i.e., proportion of HOqs to the proportion of LOqs in the two conditions) for both locations. In the Amazon, when the Puzzle Model was used, 84% of the questions created were HOqs and 16% were LOqs, whereas when the Puzzle Model was not used the opposite was true: 91.7% of the questions created were LOqs and 8.3% were HOqs.

Likewise, in the Netherlands, the same pattern was found. Of those questions created with the Puzzle Model, a significantly greater proportion were HOqs, while the questions created with the current version showed that a significantly greater proportion were not HOqs. When the Puzzle Model was used, 82.2% of the questions created were HOqs and 17.8% were LOqs, whereas when the Puzzle Model was not used 94.4% of the questions created were LOqs and 5.6% were HOqs.

Table 7
Distribution of Questions Classified as HOqs and LOqs per Location and Condition

Groups	**LOqs**	**HOqs**	**Total**
The Netherlands			
Control	17	1	18
Experimental	8	37	45
Amazon			
Control	11	1	12
Experimental	4	21	25

In order to investigate the effect sizes and test the hypotheses of effectiveness, a new variable was created taking into account the number of HOqs created by each student. A two-way ANOVA of intervention (experimental and control) and the student's location (the Netherlands or the Amazon) on effectiveness (as measured by the mean of created HOqs) was conducted. Effectiveness was analyzed in a two-way mixed factorial ANOVA, with intervention manipulated between-subjects and location as a between-subjects variable.

Table 8
Descriptive Statistics for mean number of created HOqs

	Netherlands			Amazon			Total		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Control	0.11	0.33	9	0.13	354	8	0.12	0.332	17
Experimental	2.77	1.166	13	2.10	0.876	10	2.48	1.082	23
Total	1.68	1.615	22	1.22	1.215	18	1.48	1.450	40

Note. M = mean number of HOqs; SD = standard deviation; N = number of students

A significant main effect of intervention on effectiveness was found: $F(1, 36) = 74.923$, $p < .001$, $\eta 2 = .675$. The mean number of HOqs created by students was higher when the Puzzle Model was used (M = 2.48, SD = 1.082) than when it wasn't (M = 0.12, SD = .332), supporting H1a.

Thus, the Puzzle Model significantly contributed to students' effectiveness in creating HOqs. No significant main effect of location on effectiveness was found: $F(1, 36) = 1.499$, $p = .229$, $\eta 2 = .040$, rejecting H1b. Likewise, the interaction of intervention*location was not significant: $F(1, 36) = 1.629$, $p = .210$, $\eta 2 = .210$. Thus, the effect size of intervention is significant for both locations.

Table 9
*Summary of Analysis of Variance for the factors Intervention, Location, Location*Intervention for mean number of HOqs*

Variables	**Sum of squares**	**df**	**Mean Square**	**F**	**Sig**	**Squared**
Intervention	51.971	1	51.971	74.923	0*	0.675
Location	1.040	1	1.040	1.499	0.229	0.040
Location * Intervention	1.130	1	1.130	1.629	0.210	0.043

Note: *p < .001.

6.2.2 Efficiency

Efficiency was measured by the number of questions students created within a given amount of time (within 10 minutes). A two-way ANOVA of intervention (experimental, control) and students' location (the Netherlands, Amazon) on efficiency (as measured by the mean of questions created) was conducted.

A two-way mixed factorial ANOVA, with intervention manipulated between-subjects and location as a between-subjects variable, was used to analyze Efficiency. A 2 x 2 between-subjects ANOVA was conducted on efficiency, with intervention and the students' location as factors.

Table 10
Mean number of questions created

	Netherlands			Amazon			Total		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Control	2.00	0.500	9	1.5	0.535	8	1.76	0.562	17
Experimental	3.46	1.266	13	2.5	0.527	10	3.04	1.107	23
Total	2.86	1.246	22	2.06	0.725	18	2.50	1.109	40

Note. M = mean number of questions; SD = standard deviation; N = number of students

A significant main effect of intervention on efficiency was found: $F(1, 36) = 20.52$, $p < .001$, $\eta 2 = .363$. The mean of the questions created by the students was higher when the Puzzle Model was used (M = 3.04, SD = 1.107) than when it wasn't (M = 1.76, SD = .562), supporting H2a. Thus, the use of the Puzzle Model significantly contributed to the students' efficiency on the activity of the question creation, supporting H2a.

Also, a significant effect of location on efficiency was found: $F(1, 36) = 7.23$, $p = .011$, $\eta 2 = .167$. The mean of the created questions was higher in the Netherlands (M = 2.86, SD = 1.246) than in the Amazon (M = 2.06, SD = .725). Thus, Dutch students created more questions regardless of the use of the Puzzle Model, supporting H2b. (Possible explanation: they are more used to mobile technologies). The interaction of Intervention*Location was not significant: $F(1, 36) = .722$, $p = .401$, $\eta 2 = .020$.

Table 11
*Summary of Analysis of Variance for the factors Intervention, Location, Location*Intervention for mean number of questions*

Variables	Sum of squares	df	Mean Square	F	Sig	Squared
Intervention	14.670	1	14.670	20.525	0*	0.363
Location	5.172	1	5.172	7.236	0.011**	0.167
Location * Intervention	0.516	1	0.516	0.722	0.410	0.020

Note: *p < .001 **p < .005.

The results also indicate that 36.6% of the variation and its associated error on the average amount of questions can be explained by intervention. Also, they indicate that 16.7% of the variation and its associated error can be explained by location. These results indicated that the main effect of intervention is more important than the main effect of location.

Accordingly, the Puzzle Model is likely to improve the students' efficiency in creating questions with SMILE no matter their location, although the relative difference was more pronounced among Dutch students.

Table 12
Summary of Results with hypothesis

Hypotheses	Result
Effectiveness	
H1a. The students in the experimental group create more High Order questions than the students in the control group.	Supported
H1b. The students from the Netherlands create more High Order questions than the students from the Amazon.	Rejected
Efficiency	
H2a. The students in the experimental group create more questions than the students in the control group.	Supported
H2b. The students from the Netherlands create more questions than the students from the Amazon.	Supported

6.2.3 Satisfaction

Focus Groups have been commonly applied together with other techniques in usability studies to assess users' satisfaction towards digital technologies (Lin et al., 2009; Prochaska et al., 2000; Strickler & Neafsey, 2002) and also in usability evaluation research among children (Biltoft-Jensen et al., 2014; Large, 2002). In this study, the focus groups were administered right after the experiment in order to gather qualitative data from students' perceptions related to their satisfaction in creating questions with the Puzzle Model and in the control condition.

The goal is to understand whether students of both countries were satisfied in using the puzzle version and whether there is a difference between the experimental groups of both locations. The results of the control groups were also considered, not as a parameter to compare whether the experimental groups were more satisfied than the control groups, but actually as a way to get insights into the reasons behind the results on effectiveness and efficiency. The local teachers acted as the focus groups moderators, guided by the following questions: What did you think of using SMILE? Was it difficult to create questions? Why? Was it fun to create the questions? Why? What was the most difficult part of creating the questions? What would make it easier?

In total, four focus groups were held with relatively small groups of children (composed by 9, 13, 10, and 8 students, respectively). Each focus group lasted for about 15 minutes and was conducted in the school right after the students had finished the activity of creating questions. The focus groups were recorded and students comments were transcribed. The transcriptions were analyzed for emerging themes regarding users' likes and dislikes within each condition. The results are outlined below. In order to better contextualize students' comments described, their group condition and location will be indicated between brackets when necessary. Accordingly, comments from students in the control condition were identified as "C", while comments from students in the experimental condition were identified as "E". Likewise, "NL" was used to refer to comments from students from the Netherlands by "NL", while students from the Amazon were identified as "AM".

In general, students reported enjoyment in creating questions with SMILE in both conditions and in both locations. The most common reasons the students reported liking the activity were: (1) it was online, (2) it was on mobile devices, (3) they could create their own questions, and (4) they could see their peers' questions. Repeated comments on enjoyment were related to the use of mobile devices and the fact that the activity was online, which enabled them to see their peers' questions: "*I liked it was on the tablet and online*" (E/NL), "*I liked to press the buttons on the screen… using the tablet was cool*" (E/AM)), "*It was really fun to use the tablet*" (C/AM), "*I thought it was super ultra-mega fun to see my friends' questions on the tablet*" (C/NL).

In the same vein, many students mentioned that being able to see their peers' questions was a source of enjoyment. "…*it was funny to see the questions of the others*" (E/NL), "*Seeing other friends' questions was super fun, I want to use SMIILE everyday*" (E/AM), "…*it was great to see my friends' questions and to create my question*" (C/AM). Similarly, a lot of students expressed enjoyment in creating their own questions: "*…super nice you can come up with questions and learn a lot from it*" (C/NL), "*It was fun to make questions*" (C/NL), "*I liked I could create my question*" (C/AM). Students using the Puzzle Model also expressed a sense of ownership of the questions: "*Creating my own question was nice*" (E/NL), "*I really enjoyed making my question. It was fun*" (E/AM). One student highlighted that he was satisfied with the quality of the questions he created. "*I think my questions were really good, I liked to create them*" (E/AM).

In terms of difficulties, students in both control groups, from the Netherlands and from the Amazon, noted that it was difficult to make a question because they didn't know exactly what to write. "*It was a little bit hard to come with the questions, I didn't know exactly what to write*" (C/NL), "*I didn't know what to write and where to click to create the question*" (C/AM), "*Making up a question was difficult*" (C/NL). A student from the control group of the Netherlands pointed out that the difficulty was not in SMILE itself, but in the act of creating questions. "I *don't think it was hard to make questions in SMILE, but making questions is hard*" (C/NL).

Specifically, for the students in the control group of the Amazon, digital and literacy skills were mentioned as barriers to create a question, particularly writing. "*It was a bit difficult because I had to create a long text*" (C/AM), "*Writing a question was very difficult*" (C/AM), "*…it was quite hard to write the question*" (C/AM), "*It took me a while to write the question*" (C/AM). Some of them mentioned problems directly related to digital skills. "*Find the words in the keyboard was difficult*" (C/AM), "*I didn't know where the interrogation point was*" (C/AM). And, one mentioned the theme of the lecture was difficult. "*Climate change, it was difficult to ask about that*" (C/AM).

Students of the Amazon in the experimental group also reiterated problems related to lack of digital skills. "*I didn't know which button I should press [in the keyboard] to erase what I wrote wrong*", "*I couldn't find the interrogation point*". Different from the other students from the Amazon in the control group, the students in the experimental condition did not mention writing as the main problem. Most of the difficulties they reported were related to forming a question with the Puzzle Model and completing it: "*It took some time for me to form the question and then complete the rest*", "*First, forming the question was a bit difficult*", "*I had to think a lot to complete the question*". Other problems were related to the fact that they didn't understand how the puzzle model worked at the first moment, especially the dragging down of the pieces. "*First, I didn't know how it works with the pieces*", "*I didn't understand I had to drag them down in the beginning with my (index) finger*", "*I didn't know how to move the pieces*".

The students in the experimental group of the Netherlands reported less difficulties. For many of them, creating the questions was not a problem. "*…it wasn't hard at all, it was easy to make the questions*," "*It was easy-peasy, not difficult,*" "*it wasn't difficult at all*". The difficulties pointed by them were similar to the students of the Amazon, for example, lack of understanding in how the Puzzle Model worked when they started using it. "*I couldn't get the pieces in the box when I started*", "*The dragging of the questions was hard*", "*I didn't know how to drag them*".

In terms of improvements, all groups mentioned having more time as something that would make it easier for them to create the questions. Students from the experimental groups in both locations highlighted that having more puzzle pieces would make it easier for them. "*…have other puzzles*" (E/AM), "*I guess more puzzle questions and more time to make the questions*" (E/NL). One student in the experimental condition said it would be easier for him to create a question without the Puzzle Model. "*Having no puzzle pieces would make it easier.*"

Students from both control groups observed that having some print materials with them where they could look for examples would facilitate the creation of questions, particularly having example of other questions. "*…a booklet with some information*" (C/NL), "…*to look at the climate change book" (*C/AM)*, "to have text from a book that I could look for examples*" (C/NL), "…*see some examples of other questions*" (C/AM).

7. Discussion and Conclusion

Usability is acknowledged as a crucial factor for the adoption of interactive mobile systems by the target users. The lack of usability of a system is one of the main reasons why an interactive system (people + computers) may not be successful in its practical use (Seffah et al., 2006). In that vein, this research was an attempt to improve the usability of an inquiry-based mobile learning technology, SMILE, for children of underserved communities.

The theoretical study and the heuristic evaluation led to the development of a new feature for SMILE, named the Puzzle Model, as a way of helping children to create high quality questions using this technology. Then, a usability evaluation was conducted with children from a remote village in the Brazilian Amazon without experience with mobile devices at school and also with children from the Netherlands who were familiar with the use of mobile devices at school.

The main research question this study tried to answer was: "*To what extent is the Puzzle Model usable for students from the Amazon and for students from the Netherlands?"* The idea of comparing the children from both locations was to understand whether the Puzzle Model would only be usable for the children in the Amazon, or, if this new feature would also be useful for children from a developed country who have experience with digital technologies as part of their education.

In order to investigate whether the Puzzle Model is usable for both groups of students, this study implemented a usability evaluation model based on the definition of ISO 9241-11 (International Standards Organization, 1994), assessing its three sub-constructs: effectiveness, efficiency, and satisfaction. Thus, the main research question was divided in three other sub-questions, taking into account students from both locations. First, is the Puzzle Model effective for them? Second, is the Puzzle Model efficient for them? And third, are they satisfied with it? Lastly, for each sub-question, it will be investigated whether there is a difference for the students from each location. The answers of these questions will provide an overview for the main research question raised in this study.

Is the Puzzle Model effective for them?

With this question, this study intended to assess whether or not students using the Puzzle Model could complete the task of creating high-order questions. As expected (H1a), students in the experimental group created more high-order questions than students in the control group since they received puzzle models with the beginning of questions from the application level, the first high-order level. The results indicated that the Puzzle Model was effective in helping students to create high-order questions which suggests that the incorporation of instructional features in IBL technologies, like the Puzzle Model, might facilitate children's inquiry process while using these technologies. These results are consistent with the study of Li and Lim (2008) that demonstrates that the use of fixed and adaptive scaffolds benefited students' online inquiry process. Also, it is in line with the results of Kaufman (2004), which indicate that students using prompts outperformed students in the control condition on posttests.

In terms of differences between the two locations, different from what was hypothesized, the Puzzle Model was not more effective for students from the Netherlands. In fact, students in the experimental group from both locations created a similar mean number

of high-order questions, rejecting H1b. The low numbers of high-order questions in the control groups of both locations versus the relatively high number of high-order questions in both experimental groups can be explained by studies that indicate that children's education is focused on low-order thinking and that without direct stimuli, children tend to remain in the lower levels (King, 1994; Martin et. al, 2009).

This might be the case even for children of the Amazon, with less experience with technology and less educational resources. For example, when investigating the use of digital technologies for inquiry-based practices in primary schools of Ireland, Casey & Bruce (2011) pointed that when left without support, children may not have the skills to figure out and organize their instinctive ability in the inquiry cycle. Likewise, a study conducted by King (1994), featuring the use of question stems, similar to the puzzle models, showed that when guided by the question stems, students from both grades were able to ask significantly more critical thinking questions and not many recall questions. Conversely, the unguided students "operated at the lowest level of questioning" and created mostly factual questions (King, 1994, p.357).

Is the Puzzle Model efficient for them?

With this question, this study aimed to understand the relation between the quality of the created questions (effectiveness) and the resources users expended to create the questions, which was indicated by the number of questions they could create within ten minutes. As expected (H1a), students using the Puzzle Model created more questions than the students in the control condition, since the beginning of the questions were provided to them via the Puzzle Model. Having this hypothesis confirmed suggests that the Puzzle Model was not too complicated for the students.

Otherwise, they would have spent more time to make sense of the model and create the question. In fact, the results show that even when students reported some difficulties in dragging down the pieces and forming the question, they still were more efficient than the control groups. As highlighted by Owens, Hester, and Teale (2002), when children are asked to make their own inquiries many of them don't know how to do it because "school has traditionally focused on having children to answer questions" (p.616) and not asking them. Comments of students from both control groups reiterate that conclusion and combined with the results of effectiveness and efficiency, reinforce the need for guided instruction to facilitate children's inquiry-process.

In terms of differences in efficiency between students from the two locations, as hypothesized (H1b), the students from the Netherlands created more questions than the students from the Amazon. This finding may be linked to the low levels of operational and formal skills (van Deursen, Courtois, & van Dijk, 2014) reported by students from the Amazon. These students have never used mobile technologies in their school and are generally less exposed to digital technologies when compared to students from the Netherlands. As a consequence, they spent more time creating the questions using a mobile technology. It is worth noting the fact that although the Dutch students created more questions, they didn't create more high-order questions, which suggests that the ability to create high-order question may not be correlated to the level of medium-related skills (operational and formal). This should be investigated in future studies including a paper prototype of the Puzzle Model.

Are students satisfied with the Puzzle Model?

With this question, this study aimed to understand the users' comfort and discomfort, and likes and dislikes, when using the Puzzle Model. In general, the results of the focus groups suggest that both students from the Netherlands and from the Amazon were satisfied with the activity of creating questions with the puzzle version. As showed in the results, students of both groups reported to enjoy making their own questions, to see their peers' questions, and to do it on the tablet. It is important to note that these reasons of joy mentioned by students in the experimental group are not different from the reasons mentioned by the students in the control group and thus, suggest that using the Puzzle Model did not attenuate the characteristics intrinsic to SMILE that makes children enjoy the experience.

However, the Puzzle Model seems to reduce the difficulties associated with "coming up with a question" or "writing a question" as mentioned by students from the control groups. In fact, different from the control groups, most of the difficulties pointed out by students using the Puzzle Model were less related to creating a question and more linked to the fact they were using the Puzzle Model for the first time. For example, how to drag down the pieces. In this case, lack of provided instruction during the experiment or the lack of instruction built within the Puzzle Model, like "click here to drag down each piece", might be the causes. To better investigate this issue, new studies with the Puzzle Model should be conducted using a screen recording and thinking aloud procedures.

Nevertheless, the students of the Amazon, particularly mentioned more problems, such as a lack of understanding on how to form the question and how to complete it. Also, this group reported problems related to operational and formal skills required to operate digital media and to handle its structures (van Deursen, Courtois, & van Dijk, 2014), which suggests that the lack of those basic skills may have an impact on their perceived satisfaction with the use of the Puzzle Model since students from the Netherlands reported considerably less difficulties than students from the Amazon. To get a better understanding of this issue, future studies should incorporate digital skill measurements in the design of the study.

Although Dutch students reported a higher level of enjoyment in creating questions with the Puzzle Model, one student commented that the absence of puzzle pieces would make it easier for him to create the questions. Although a single comment, it draws attention to one of the possible drawbacks of adding instructional features to inquiry-based technologies, which is the design of a too-complex or restricted activity. Additional attention should be paid to this matter in future studies. In terms of the restrictiveness of the Puzzle Model, it is important to note that both experimental groups mentioned that question ownership was a reason for enjoyment of the activity. These comments indicate that they didn't feel restricted by creating inquiries with the question stems. Actually, they enjoyed it, and some even reported to be surprised that their questions were too good.

To what extent is the Puzzle Model usable for students from the Amazon and for students from the Netherlands?

Lastly, making sense of the three subcontracts of usability, this study attempted to answer the main research question on what extent the Puzzle Model is usable for students of both locations. First, since neither a main interaction effect or a main effect for location was found, but only a main effect for intervention, it can be concluded that the Puzzle Model was effective for all students in the experimental group, regardless of whether they were from the Netherlands or the Amazon.

Second, since there was no main interaction effect, but there was a main effect for intervention and for location, it can be concluded that the Puzzle Model was efficient for all students in the experimental group, regardless of whether they were from the Netherlands or from the Amazon. However, the Puzzle Model was even more efficient for the students of the Netherlands.

Lastly, based on their comments in the focus group, it can be concluded that students in both experimental groups were satisfied using the Puzzle Model. Nevertheless, students from the Netherlands reported a higher level of satisfaction since they mentioned fewer difficulties in operating the system than students in Brazil. In sum, the Puzzle Model is usable for both students from the Amazon and for students from the Netherlands, with a higher usability for the Dutch students, as hypothesized and previously discussed.

7.1 Implications Of The Study And Directions For Future Research

As a pilot study, this research presents some shortcomings, mainly associated with the choice of doing a field experiment in different countries within 1 year. These limitations are due to the lack of control to extraneous variables, typical of the field experiments which might make the results less reliable. For example, the number of students (total and per condition), their grade and age, and everything that happens during the experiment in a classroom, children who communicate with each other, children who want to participate in a later session of the experiment, and all sorts of things that are out of the control of the researcher. However, as a pilot study in its nature, it raises a number of opportunities for future research, both in terms of theory and validation. More research will, in fact, be necessary to refine and further enhance the Puzzle Model of SMILE.

First, it would be advisable to have larger samples across more schools in comparable contexts to avoid a bias. Second, satisfaction needs to be further examined with the employment of different methods from focus groups. Although the comments of the students are a valid source of explanation for the results, doing a focus group after a one-hour experiment when children are eager to go out of the class and play is not the best strategy.

Also, to better investigate whether the Puzzle Model needs to provide more instructions in the interface, new studies should be conducted using screen recordings and thinking aloud procedures. Likewise, for future studies, it would be advisable to measure children's digital skills and investigate whether this may have an impact on their perceived satisfaction and effectiveness. For the latter, studies including a paper prototype of the Puzzle Model would be ideal.

Additionally, to really access the potential of the new Puzzle Model as a tool to enhance critical thinking via inquiry-based learning, longitudinal research is needed. This means the development of an entire course, comprising teacher training and other supporting materials with a minimum length of one year, measuring students' achievements. In such case, the alternation of the use of the Puzzle Model with the basic version of SMILE

is highly recommendable, since it is important that children learn how to make high-order questions without the prompts. Also, such elaboration must also focus on stimulating students to add possible answers to their questions (multiple choice), to go to the field (for observing an event and taking pictures), as well as to debate around the created questions and, lastly, to create questions in peers (groups of 2 or 3 students per device).

As a final conclusion, it is important to address the goal of the study, which was to deepen the comprehension of how to support a mobile inquiry-based learning platform in order to enhance children's critical understanding regarding real world problems. In order to achieve that, this study investigated, designed, and evaluated a new instructional feature for SMILE, the Puzzle Model. Accordingly, the major practical contribution of the present research is that it provides students and teachers with a tool that has the potential to facilitate and gradually improve their inquiry process via the “puzzle question starters” which is based on a critical thinking framework (Bloom, 1956). Moreover, the flexibility of the Puzzle Model makes it a tool that can be used within any subject, from complex sustainability issues to basic math concepts. Additionally, it is a tool proven to be usable by children from extremely different contexts, from developed countries, and also underserved communities. In a nutshell, it is a useful tool with the potential to contribute to the achievement of a sustainable world via critical education for new generations, featuring affordable technology.

References

Albirini, A. (2007). The Crisis of Educational Technology, and the Prospect of Reinventing Education. *Educational Technology & Society*, 10 (1), 227-236.

Ali, A., Alrasheedi, M., Ouda A., Capretz, L.F. (2015). A study of the interface usability issues of mobile learning applications for smart phones from the user's perspectives. *International Journal on Integrating Technology in Education*, 3(4), 3-16.

Anderson, L. W., Krathwohl, D. R., Airiasian, W., Cruikshank, K. A., Mayer, R. E., & Pintrich, P. R. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational outcomes: Complete edition*. NY: Longman.

Attewell, J. (2005). From research and development to mobile learning: Tools for education and training providers and their learners. *Proceedings of mLearn 2005*. Retrieved from: http://http://iamlearn.org/mlearn-archive/mlearn2005/CD/papers/Attewell.pdf [Accessed 21 April 2017]

Baruzzi, R. G.. (2007). A universidade na atenção à saúde dos povos indígenas: a experiência do Projeto Xingu da Universidade Federal de São Paulo/Escola Paulista de Medicina. *Saúde e Sociedade*, 16(2), 182-186.

Biltoft-Jensen, A., Trolle, E., Christensen, T., Islam, N., Andersen, L. F., Egenfeldt-Nielsen, S., & Tetens, I. (2014). WebDASC: a web-based dietary assessment software for 8–11-year-old Danish children. J*ournal of Human Nutrition and Dietetics*, 27(s1), 43-53.

Black, M., & Edgar, W. (2009). Exploring mobile devices as grid resources: Using an x86 virtual machine to run boinc on an iPhone. In: *10th IEEE/ACM International Conference on Grid Computing*, Washington, DC, USA, pp 9-16,.

Bloom, B. S. (1956). T*axonomy of educational objectives*. Vol. 1: Cognitive domain. New York: McKay.

Buckner, E., & Kim, P.. (2014). *Integrating technology and pedagogy for inquiry based learnin*g: The Stanford Mobile Inquiry-based Learning Environment (SMILE). UNESCO.

Casey, L., & Bruce, B. C. (2011). The practice profile of inquiry: Connecting digital literacy and pedagogy. *E-learning and Digital Media*, *8*(1), 76-85.

Conklin, J. (2005). A Taxonomy for learning, teaching and assessing: a revision of Bloom's taxonomy of educational objectives. *Educational Horizons*, Lambda Theta, v.83, n.3, p.153-159, Mar.

Ferraz, A. P. D. C. M. (2008). *Instrumento para facilitar o processo de planejamento e desenvolvimento de materiais instrucionais para a modalidade a distância* (Doctoral dissertation, Universidade de São Paulo).

Frøkjær, E., Hertzum, M., & Hornbæk, K. (2000). Measuring usability: Are effectiveness, efficiency and satisfaction really correlated? In: *Proceedings of CHI 2000 Human Factors in Computing Systems* (pp. 345–352). ACM Press

Gelder, T. V. (2005). Teaching critical thinking: Some lessons from cognitive science. *College teaching*, *53*(1), 41-48.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. *American psychologist*, *53*(4), 449.

Hwang, G. J., Wu, P. H., Zhuang, Y. Y., & Huang, Y. M. (2013). Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students. I*nteractive Learning Environments*, 21(4), 338-354.

ISA, Instituto Socioambiental (2017). Alto Xingu. Retrieved from: https://www.socioambiental.org/pt-br/tags/alto-xingu [Accessed 21 April 2017]

ISO 9241. 1992/2001. *Ergonomics Requirements for Office with Visual Display Terminals (VDTs)*, Geneva, International Organization for Standardization.

Kauffman, D.F. (2004). Self-regulated learning in web-based environments: Instructional tools designed to facilitate cognitive strategy use, metacognitive processing, and motivational beliefs. *Journal of Educational Computing Research*, 30, 139–161.

Kim, P., & An, J. Y. (2016). New Evaluation Vector through the Stanford Mobile Inquiry-Based Learning Environment (SMILE) for Participatory Action Research. *Healthcare informatics research*, *22*(3), 164-171.

Kim, P., Buckner, E., Kim, H., Makany, T., Taleja, N., & Parikh, V. (2012). A comparative analysis of a game-based mobile learning model in low-socioeconomic communities of India. *International Journal of Educational Development*, 32(2), 329-340.

Kim, P., Kim, H., Parikh, V., Taleja, N., Lim, G., & Freedman, N. (2009). Mobile technology as empowerment tool for the underserved. In: *Proceedings of 2009 IEEE - Conference on Technologies for Humanitarian Challenges*.

Kim, P., & An, J. Y. (2016). New Evaluation Vector through the Stanford Mobile Inquiry-Based Learning Environment (SMILE) for Participatory Action Research. *Healthcare informatics research*, 22(3), 164-171.

King, A. (1990). Enhancing Peer Interaction and Learning in the Classroom Through Reciprocal Questioning. *American Educational Research Journal*, 27(4), 664-687.

Kramarski, B., & Gutman, M. (2006). How can self-regulated learning be supported in mathematical E-learning environments? *Journal of Computer Assisted Learning,* 22, 24–33.

Kukulska-Hulme, A. (2005). Mobile usability and user experience. In A. Kukulska-Hulme, & J. Traxler (Eds.), *Mobile learning: A handbook for educators and trainers* (pp. 45–56). London: Routledge.

Kukulska-Hulme, A., & Traxler, J. (2007). Learning design with mobile and wireless technologies. In H. Beetham, & R. Sharpe (Eds.), *Rethinking pedagogy for the digital age*: Designing and delivering e-learning (pp. 180–192). London, UK: Routledge.

Lakkala, M., Lallimo, J., & Hakkarainen, K. (2005). Teachers' pedagogical designs for technology-supported collective inquiry: A national case study. *Computers & Education*, 45(3), 337-356.

Lai, E. R. (2011). Critical thinking: A literature review. *Pearson's Research Reports*, *6*, 40-41.

Large, A., Beheshti, J., & Rahman, T. (2002). Design criteria for children's Web portals: The users speak out. J*ournal of the Association for Information Science and Technology*, 53(2), 79-94.

Li, D. D., & Lim, C. P. (2008). Scaffolding online historical inquiry tasks: A case study of two secondary school classrooms. *Computers & Education*, 50(4), 1394-1410.

Lim, B.R. (2004). Challenges and issues in designing inquiry on the Web British. *Journal of Educational Technology*, 35 (5), pp. 627–643.

Lin, C. A., Neafsey, P. J., & Strickler, Z. (2009). Usability testing by older adults of a computer-mediated health communication program. *Journal of Health Communication*, 14(2), 102-118.

Manlove, S., Lazonder, A.W., & de Jong, T. (2006). Regulative support for collaborative scientific inquiry learning. *Journal of Computer Assisted Learning*, 22, 87–98.

Manlove, S., Lazonder, A. W., & de Jong, T. (2009). Collaborative versus individual use of regulative software scaffolds during scientific inquiry learning. *Interactive Learning Environments*, 17(2), 105-117.

Martin, R. E., Sexton, C. M., Franklin, T. J., Gerlovich, J. A., & McElroy, D. (2009). *Teaching science for all children: An inquiry approach*. New York, NY: Pearson.

Marquardt, M. J. (2011). *Leading with questions: How leaders find the right solutions by knowing what to ask* (Vol. 180). John Wiley & Sons.

Ololube, N. P., Ubogu, A. E., & Ossai, A. G. (2007). *ICT and Distance Education in Nigeria*, A review of Literature and Accounts. In: International Open and Distance Learning (IODL) Symposium.

Olson, S. & Loucks-Horsley, S. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*. Washington, DC: National Academies Press.

Owens, R. F., Hester, J. L., & Teale, W. H. (2002). Where do you want to go today? Inquiry-based learning and technology integration. *Reading Teacher*, 55(7), 616.

Paul, R. (1992). Critical thinking: What, why, and how. *New directions for community colleges*, *1992*(77), 3-24.

Prochaska, J. J., Marion, M. S., Zabinski, F., Calfas, K. J., Sallis, J. F., & Patrick, K. (2000). Interactive communication technology for behavior change in clinical settings. *American Journal of Preventive Medicine*, 19(2), 127–131.

Quesenbery, W. (2003). *The five dimensions of usability* (Vol. 20, pp. 89-90). Mahwah, NJ: Lawrence Erlbaum Associates.

Ramos, V. D. (2015). *Integration of ICT into an adult education program for indigenous communities*. The case of Guainía, Colombia (Mather thesis).

Raza, A., Capretz, L.F. & Ahmed, F. (2012) "Users' perception of open source usability: An empirical study", *Engineering with Computers*, Springer, vol. 28, No 2, p. 109-121.

Righton, N. & Koene, T. (2010). *Help, mijn iglo smelt!*. Rotterdam, The Netherlands: Lemniscat.

Rusten, E. (2003) Using Computers in Schools. In *Digital Opportunities for Development*: A Sourcebook for Access and Applications. Retrieved from http://learnlink.aed.org/Publications/Sourcebook/chapter4/Computers_in_ Schools_modelofuse.pdf.

Salomon, G. (2002). Technology and pedagogy: why don't we see the promised revolution? *Educational technology*, 42 (1), 71-75.

Seffah, A., Donyaee, M., Kline, R. B., & Padda, H. K. (2006). Usability measurement and metrics: A consolidated model. *Software Quality Journal*, 14(2), 159-178.

Sharples, M., Taylor, J. & Vavoula, G.N., 2005. *Towards a theory of mobile learning*. In: Paper Presented at the 4th World Conference on mLearning.

Shih, J.-L., Chuang, C.-W., & Hwang, G.-J. (2010). An Inquiry-based Mobile Learning Approach to Enhancing Social Science Learning Effectiveness. *Educational Technology & Society*, 13 (4), 50 62.

Shin, N., Norris, C. & Soloway, E. (2006). Effects of handheld games on students learning in mathematics. In: Paper Presented at the Proceedings of the *7th International Conference on Learning Science*s.

Strickler, Z., & Neafsey, P. J. (2002). Visual design of interactive software for older adults: Preventing drug interactions in older adults. *Visible Language*, 36(1), 4–28.

Strijbos, J.W., Martens, R.L., & Jochems, W.M.G. (2004). Designing for interaction: Six steps to designing computer-supported group-based learning. *Computers & Education,* 42(4), 403- 424.

Swart, A. J. (2010). Evaluation of final examination papers in engineering: A case study using Bloom's Taxonomy. *IEEE Transactions on Education*, *53*(2), 257-264.

Traxler, J. and Leach, J. (2006) Innovative and sustainable mobile learning in Africa, In 4th IEEE *International Workshop on Wireless, Mobile and Ubiquitous Technology in Education*, Los Alamitos, USA, pp 98-102.

Ucar, S. & Trundle, K.C. (2011). Conducting guided inquiry in science classes using authentic, archived, web-based data. *Computers & Education*, 57 (2), pp. 1571–1582

UN, United Nations (2016). *Transforming our world: the 2030 Agenda for Sustainable Development*. United Nations General Assembly; New York, NY, USA; Sept 25, 2015.

UNICEF, United Nations Children's Fund (2016). *The State of the world's children: a fair chance to every child*. No. 01. UNICEF, New York, June 2016, p.172.

Wang, S. & Dey, S. (2013) Adaptive mobile cloud computing to enable rich mobile multimedia applications. In: *IEEE Transactions on Multimedia*, pp 1-14.

Warschauer, M. & Ames, M. (2010). Can One Laptop per Child save the world's poor. *Journal of International Affairs*. 64 (1):33–51.

van Deursen, A. J., Courtois, C., & van Dijk, J. A. (2014). Internet skills, sources of support, and benefiting from Internet use. *International journal of human-computer interaction*, 30(4), 278-290.

World Commission on Environment and Development, *Our Common Future* (Oxford: Oxford University Press, 1987).

World Wildlife Fund (2017). *Climate Change in the Amazon*. Retrieved from: wwf.panda.org [Accessed 21 April 2017]

Wu, W. H., Wu, Y. C. J., Chen, C. Y., Kao, H. Y., Lin, C. H., & Huang, S. H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education*, 59(2), 817-827.

Zurita, G., & Nussbaum, M. (2004). A constructivist mobile learning environment supported by a wireless handheld network. *Journal of Computer Assisted Learning*, 20(4), 235-243.

Appendices

Appendix 1 - Puzzle questions by level in English, Portuguese and Dutch

Level 1 - Knowledge
Nível 1 - Conhecimento
Niveau 1 - Kennis

- 1.1 What is the definition of … ?
- 1.1 Qual é a definição de …?
- 1.1 Wat is de definitie van ...?
- 1.2 What is the meaning of…?
- 1.2 Qual é o significado de …?
- 1.2 Wat is de betekenis van ...?
- 1.3 What are the effects of …?
- 1.3 Quais são os efeitos de …?
- 1.3 Wat zijn de gevolgen van ...?
- 1.4 What happened after…?
- 1.4 O que aconteceu após …?
- 1.4 Wat is er gebeurd na ...?
- 1.5 What happened before…?
- 1.5 O que aconteceu antes …?
- 1.5 Wat is er gebeurd voor … ?

Level 2 - Comprehension
Nível 2 - Compreensão
Niveau 2 - Begrip

- 2.1 What is the main idea of…?
- 2.1 Qual foi a idéia principal…?
- 2.1 Wat was het belangrijkste idee van ...?
- 2.2 What is the main problem of...?
- 2.2 Qual é o principal problema de …?
- 2.2 Wat is het belangrijkste probleem van ...?
- 2.3 How would you summarize … ?
- 2.3 Como você resumiria …?
- 2.3 Wat is je samenvatting van…?
- 2.4 Which facts indicate...?
- 2.4 Quais fatos indicam …?
- 2.4 Welke feiten geven aan ...?
- 2.5 What problems are related to...?
- 2.5 Que problemas estão relacionados a …?
- 2.5 Welke problemen horen bij ...?

Level 3 - Application
Nível 3 - Aplicação
Niveau 3 - Toepassing

- 3.1 What would you improve …?
- 3.1 O que você melhoraria …?
- 3.1 Wat zou je verbeteren aan …?
- 3.2 What would you solve first…?
- 3.2 O que você resolveria primeiro...?
- 3.2 Wat zou je eerst oplossen ...?
- 3.3 What would you change first...?
- 3.3 O que você mudaria primeiro…?
- 3.3 Wat zou je eerst veranderen ...?

3.4 What would you do…?
3.4 O que você faria …?
3.4 Wat zou je doen ...?
3.5 How would you use…?
3.5 Como você usaria …?
3.5 Hoe gebruik je …?

Level 4 - Analysis
Nível 4 - Análise
Niveau 4 - Analyse

4.1 What is not a problem related to…?
4.1 O que não é um problema relacionado a …?
4.1 Welk probleem hoort niet bij ...?
4.2 What are the causes of…?
4.2 Quais são as causas de…?
4.2 Wat zijn de oorzaken van ...?
4.3 What are the consequences of…?
4.3 Quais são as conseqüências de …?
4.3 Wat zijn de gevolgen van ...?
4.4 What is similar to…?
4.4 O que é semelhante a …?
4.4 Wat is vergelijkbaar met ...?
4.5 What could have happened if…?
4.5 O que poderia ter acontecido se ...?
4.5 Wat zou er kunnen gebeuren als ...?

Level 5 - Synthesis
Nível 5 - Síntese
Niveau 5 - Synthese

5.1 How would you improve…?
5.1 Como você melhoraria …?
5.1 Wat zou je verbeteren aan …?
5.2 What is a possible solution to…?
5.2 Qual é uma possível solução para …?
5.2 Wat is een mogelijke oplossing voor ...?
5.3 What can happen if…?
5.3 O que pode acontecer se …?
5.3 Wat kan er gebeuren als ...?
5.3 What is not a possible solution to…?
5.3 O que não é uma solução possível para …?
5.3 Wat is geen mogelijke oplossing voor ...?
5.5 What is the best way to solve …?
5.5 Qual é a melhor maneira de resolver …?
5.5 Wat is de beste oplossing voor …?

Level 6 - Evaluation
Nível 6 - Avaliação
Niveau 6 - Evaluatie

6.1 Why do you agree with…?
6.1 Por que você concorda com …?
6.1 Waarom ben je het eens met ...?
6.2 What are the disadvantages of…?
6.2 Quais são as desvantagens de …?
6.2 Wat zijn de nadelen van ...?
6.3 What would you recommend to…?
6.3 O que você recomendaria para …?
6.3 Wat zou je aanraden aan ...?
6.4 Which is more important than…?
6.4 Qual é mais importante que …?
6.4 Wat is belangrijker dan ...?

6.5 What are the advantages of…?
6.5 Quais são as vantagens de …?
6.5 Wat zijn de voordelen van ...?

Appendix 2 - Questions per level of Bloom's taxonomy

		Question	Bloom Level	Condition	Location
1	1005	is het vaak donker op de noordpool? Is it often dark on the north pole?	L1 - Knowledge	Control	the Netherlands
2	1006	hoeveel mensen gaan dood in etiopie. How many people die in ethiopia	L1 - Knowledge	Control	the Netherlands
3	1007	hoeveel mensen gaan er dood in eetiopie How many people die in ethiopia	L1 - Knowledge	Control	the Netherlands
4	1009	hoe lang duurt voor het eiland overstroomt How long does it take before the island overflows?	L1 - Knowledge	Control	the Netherlands
5	1005	wat is een eiland What is an island	L1 - Knowledge	Control	the Netherlands
6	2003	is klimaatverandering erg? Is climate change very bad?	L1 - Knowledge	Experimental	the Netherlands
7	3001	Quantas pessoas morrem? How many people die?	L1 - Knowledge	Control	Amazon
8	3002	Quantos bichos morrem? How many animals die?	L1 - Knowledge	Control	Amazon
9	3005	Onde esta acontecendo o desmatamento ? Where is deforestation happening?	L1 - Knowledge	Control	Amazon
10	3006	Aquecimento global é ruim? Is global warming bad?	L1 - Knowledge	Control	Amazon
11	3002	O que é mudança climática? What is climate change?	L1 - Knowledge	Control	Amazon
12	3001	Onde fica polo norte? Where is the North Pole?	L1 - Knowledge	Control	Amazon
13	3003	Por que a agua fica seca? Why does the water get dry?	L2 - Comprehension	Control	Amazon
14	3007	Por que está acontecendo a seca? Why is drought happening?	L2 - Comprehension	Control	Amazon
15	3008	Por que a lagoa ficou seca? Why did the lake become dry?	L2 - Comprehension	Control	Amazon
16	3005	Por que cortam a árvore? Why do they cut trees?	L2 - Comprehension	Control	Amazon

17	3004	Quando começou o aquecimento global?	L2 - Comprehension	Control	Amazon
		When did global warming start?			
18	4006	Como você usa tablet?	L2 - Comprehension	Experimental	Amazon
		How do you use a tablet?			
19	4009	Como você usa iglu?	L2 - Comprehension	Experimental	Amazon
		How do you use an igloo?			
20	4010	Como você usa barco?	L2 - Comprehension	Experimental	Amazon
		How do you use a boat?			
21	4008	Como você usaria arranhadera?	L2 - Comprehension	Experimental	Amazon
		How do you use arranhadeira?			
22	1001	waarom kappen ze bomen om	L2 - Comprehension	Control	the Netherlands
		Why do they cut trees			
23	1002	Waarom smelt ijs zo snel?	L2 - Comprehension	Control	the Netherlands
		Why does ice melt so fast?			
24	1003	wat gebeurt er als de aarde opwarmt	L2 - Comprehension	Control	the Netherlands
		What happens when the earth warms up?			
25	1004	hoe komen ze in etiopïe aan kogels en geweren	L2 - Comprehension	Control	the Netherlands
		How do they get into bullets and rifles in Ethiopia?			
26	1008	Warom willen mensen in etyopië niet delen met water?	L2 - Comprehension	Control	the Netherlands
		Why do people in Ethiopia do not want to share water?			
27	1006	waarom smelt het ijs.	L2 - Comprehension	Control	the Netherlands
		Why does the ice melt			
28	1002	wat kan er gebeuren met het eiland van Toei?	L2 - Comprehension	Control	the Netherlands
		What can happen to Toei Island?			
29	1001	waarom hebben de indianen een doek om hun middel.	L2 - Comprehension	Control	the Netherlands
		Why do the Indians have a cloth around their waist?			
30	1009	hoelang duurt het dat de noordpool overstroomt	L2 - Comprehension	Control	the Netherlands
		How long before the north pole will overflow?			
31	1003	hoe krijgen ze geweren en kogels	L2 - Comprehension	Control	the Netherlands
		How do they get guns and bullets			
32	1006	hoe komen de manen aan geweren	L2 - Comprehension	Control	the Netherlands
		How do the men get guns			

33	1008	Wat gebeurt er als een eiland overstroomt?	L2 - Comprehension	Control	the Netherlands
		What happens when an island flood?			
34	2007	Hoe gebruik je een computer?	L2 - Comprehension	Experimental	the Netherlands
		How do you use a computer?			
35	2010	Hoe gebruik je een speer om in de Amazone te jagen?	L2 - Comprehension	Experimental	the Netherlands
		How do you use a spear to hunt in the Amazon?			
36	2011	Hoe gebruik je een speer?	L2 - Comprehension	Experimental	the Netherlands
		How do you use a spear?			
37	2005	Hoe gebruik je water in de woestijn	L2 - Comprehension	Experimental	the Netherlands
		How do you use water in the desert?			
38	2003	Hoe gebruik je vuur	L2 - Comprehension	Experimental	the Netherlands
		How do you use fire?			
39	2002	Hoe gebruik je een pijl en boog	L2 - Comprehension	Experimental	the Netherlands
		How do you use an arrow and bow?			
40	2009	Hoe gebruik je een speer om te jagen	L2 - Comprehension	Experimental	the Netherlands
		How do you use a spear to hunt			
41	1004	hoe kan toei zijn oogst beschermen	L3 - Application	Control	the Netherlands
		How can they protect his harvest?			
42	2005	Wat zou je eerst veranderen aan de Amazone	L3 - Application	Experimental	the Netherlands
		What would you first change to the Amazon?			
43	2006	Wat zou je eerst veranderen aan Toey leven?	L3 - Application	Experimental	the Netherlands
		What would you first change to Toey life?			
44	2003	Wat zou je doen aan toey leven	L3 - Application	Experimental	the Netherlands
		What would you do to toeis life?			
45	2001	Wat zou je verbeteren aan de klimaatverandering?	L3 - Application	Experimental	the Netherlands
		What would you improve on climate change?			
46	2002	Wat zou je verbeteren aan de gekapte bossen	L3 - Application	Experimental	the Netherlands
		What would you improve on the chopped forests			
47	2002	Wat zou je eerst oplossen aan klimaatverandering	L3 - Application	Experimental	the Netherlands
		What would you first resolve on climate change			
48	2008	Wat zou je eerst veranderen aan de noordpool?	L3 - Application	Experimental	the Netherlands
		What would you first change to the north pole?			
49	2003	Wat zou je eerst oplossen aan de woestijn?	L3 - Application	Experimental	the Netherlands

		What would you first solve about the desert?			
50	2008	Wat zou je verbeteren aan de woestijn?	L3 - Application	Experimental	the Netherlands
		What would you improve on the desert?			
51	2006	Wat zou je verbeteren aan de Amazone ontbossing	L3 - Application	Experimental	the Netherlands
		What would you improve on the Amazon deforestation			
52	2008	Wat zou je doen met de overstroming op de eilanden?	L3 - Application	Experimental	the Netherlands
		What would you do with the floods on the islands?			
53	2008	Hoe gebruik je water in de woestijn?	L3 - Application	Experimental	the Netherlands
		How do you use water in the desert?			
54	2010	Wat zou je eerst veranderen aan het klimaat?	L3 - Application	Experimental	the Netherlands
		What would you first change to the climate?			
55	2007	Wat zou je eerst oplossen in de fabrieken?	L3 - Application	Experimental	the Netherlands
		What would you first solve in the factories?			
56	2013	Wat zou je eerst veranderen in de fabrieken	L3 - Application	Experimental	the Netherlands
		What would you change in the factories			
57	2002	Wat zou je eerst veranderen aan de noordpool	L3 - Application	Experimental	the Netherlands
		What would you change to the north pole			
58	2002	Wat zou je doen aan klimaatverandering in de school?	L3 - Application	Experimental	the Netherlands
		What would you do about climate change at school?			
59	2001	Wat zou je eerst veranderen aan de klimaatverandering?	L3 - Application	Experimental	the Netherlands
		What would you first change on climate change?			
60	2011	Wat zou je verbeteren aan het klimaatprobleem	L3 - Application	Experimental	the Netherlands
		What would you improve on the climate problem			
61	2006	Hoe gebruik je je water in de woestijn	L3 - Application	Experimental	the Netherlands
		How do you use your water in the desert?			
62	2005	Wat zou je verbeteren aan de Amazone	L3 - Application	Experimental	the Netherlands
		What would you improve on the Amazon			
63	2008	Wat zou je eerst oplossen aan de verontreiniging in china?	L3 - Application	Experimental	the Netherlands
		What should you first solve about he pollution in China?			

64	2012	Wat zou je eerst veranderen aan de vieze fabrieken?	L3 - Application	Experimental	the Netherlands
		What would you first change to the dirty factories?			
65	2003	Wat zou je verbeteren aan water in afrika	L3 - Application	Experimental	the Netherlands
		What would you improve on water in Africa			
66	2013	Wat zou je verbeteren aan het gas	L3 - Application	Experimental	the Netherlands
		What would you improve on the gas			
67	2011	Wat zou je eerst oplossen om het klimaat	L3 - Application	Experimental	the Netherlands
		What would you first solve the climate			
68	3004	Por que o incêndio queima a roça?	L3 - Application	Control	Amazon
		Why does the incendie burn the crops?			
69	4001	O que você resolveria primeiro na Amazonia?	L3 - Application	Experimental	Amazon
		What would you solve first in the Amazon?			
70	4002	O que você melhoraria ne Polo Norte	L3 - Application	Experimental	Amazon
		What would you improve in the North Pole?			
71	4003	O que você mudaria primeiro na amazonia?	L3 - Application	Experimental	Amazon
		What would you first change in the Amazon?			
72	4004	O que você mudaria primeiro no aquecimento global?	L3 - Application	Experimental	Amazon
		What would you first change on global warming?			
73	4003	O que você resolveria primeiro no aquecimento global?	L3 - Application	Experimental	Amazon
		What would you first solve on global warming?			
74	4002	O que você faria com incêndio na floresta	L3 - Application	Experimental	Amazon
		What would you do with the forest fires?			
75	4004	O que você resolveria primeiro na aldeia?	L3 - Application	Experimental	Amazon
		What would you first solve at the village?			
76	4002	O que você mudaria primeiro para ajudar Toei	L3 - Application	Experimental	Amazon
		What would you first change to help Toei			
77	4001	O que você melhoraria agora no xingu?	L3 - Application	Experimental	Amazon
		What you would improve now on Xingu?			
78	4007	O que você melhoraria na floresta Amazonia	L3 - Application	Experimental	Amazon
		What would you improve in the Amazon rainforest?			
79	4008	O que voce mudaria primeiro no xingu?	L3 - Application	Experimental	Amazon
		What would you first change in Xingu?			

80	4010	O que você mudaria primeiro no desmatamento de arevores? What would you first change in the deforestation of trees?	L3 - Application	Experimental	Amazon
81	4010	O que voce melhoraria na escola? What would you improve at school?	L3 - Application	Experimental	Amazon
82	4004	O que você faria quando rio seca? What would you do when the river is dry?	L3 - Application	Experimental	Amazon
83	4006	O que você melhoraria no clima What would you improve on climate?	L3 - Application	Experimental	Amazon
84	4007	O que você resolveria primeiro na escola What would you solve at school?	L3 - Application	Experimental	Amazon
85	4009	O que você faria para acabar com aquecimento global? What would you do to stop global warming?	L3 - Application	Experimental	Amazon
86	4005	O que você melhoraria na aldeia, agua What would you improve in the village, water?	L3 - Application	Experimental	Amazon
87	2003	Wat zou je eerst veranderen om klimaatverandering te stoppen? What would you first change to stop climate change?	L4 - Synthesis	Experimental	the Netherlands
88	2004	Wat zou je eerst veranderen om klimaatverandering te helpen? What would you first change to help climate change?	L4 - Synthesis	Experimental	the Netherlands
89	2007	Wat zou je eerst veranderen on de uitsterving te stoppen ? What would you first change to stop the extinction	L4 - Synthesis	Experimental	the Netherlands
90	2009	Wat zou je verbeteren aan het leven in de Amazone What would you improve to live well in the Amazon?	L4 - Synthesis	Experimental	the Netherlands
91	2004	Wat zou je eerst oplossen om de houtsnede te stoppen? What would you first solve to stop the woodcut?	L4 - Synthesis	Experimental	the Netherlands
92	2006	Wat zou je eerst oplossen zo dat er geen bomen worden gekapt What would you first solve so that no trees are cut	L4 - Synthesis	Experimental	the Netherlands
93	2009	Wat zou je eerst oplossen om goed te kunnen leven in de Amazone?	L4 - Synthesis	Experimental	the Netherlands

		What would you first solve to live well in the Amazon?			
94	2004	Wat zou je doen om de opwarming van de aarde te stoppen	L4 - Synthesis	Experimental	the Netherlands
		What would you do to stop global warming			
95	2012	Wat zou je eerst oplossen om goet te kunnen leven in de woestijn?	L4 - Synthesis	Experimental	the Netherlands
		What would you first solve to have a good life in the desert?			
96	2004	Wat zou je doen om een iglo verbeteren als hij smelt	L4 - Synthesis	Experimental	the Netherlands
		What would you do to improve an igloo as it melts			
97	4005	Como você usa a agua para acabar com incêndio	L4 - Synthesis	Experimental	Amazon
		How do you use water to stop forest fires?			
98	4005	O que você resolveria primeiro pra ter menos seca?	L4 - Synthesis	Experimental	Amazon
		What would you first solve to have less drought?			
99	2001	Wat zou je doen als het oerwoud weg was?	L5 - Synthesis	Experimental	the Netherlands
		What would you do if the jungle was gone?			
100	4003	O que você faria quando rio ficar sem peixe?	L5 - Synthesis	Experimental	Amazon
		What would you do when there are no more fishes in the river?			

Appendix 3 - Lecture Slides in Dutch and in Portuguese

Dutch


Overleven in de Jungle
Ontbossing in de Amazone beïnvloedt de wereld. Minder bomen betekenen minder zuurstof. Het doden van bomen draagt bij aan de opwarming van de aarde
Rond het dorp van Tepkatsie, in de Amazone, zijn er geen bomen meer Boeren verkopen het hout en branden alles om sojabonen te planten
Brazilië
Tepkatsie
Er is niet veel jungle overgelaten voor hem en zijn familie om te jagen
Vanwege grootschalige landbouw, zijn er veel slechte stoffen in het water van de rivier

Portuguese


Mudanças Climáticas:
Como jovens em diferentes continentes estão sentindo isso
Jemery
Tepkatsie
Halima
Toei


Pólo Norte
Jemery
Jeremy não pode dormir no iglu porque o iglu derrete
Ajude! O meu iglu derrete!
O gelo está menos confiável. Esquimós morrem enquanto caçam, porque o gelo quebra
A família de Jeremy se perde na neve porque os ventos estão mais fortes devido ao aquecimento global
Ursos polares tem que nadar muito tempo para encontrar gelo para caçar e morrem afogados
2


Sobrevivência no deserto
Acontecem guerras entre as tribos pois não tem água para todos
Halima cuida das cabras. Alguns anos atrás, ela tinha que caminhar 30 minutos para encontrar água e capim para alimentar as cabras, agora ela tem que caminhar cinco horas, por causa da seca
Halima
Etiópia
Muitos rios pequenos agora estão secos e não tem água
Os animais ficam fracos e morrem pois tem pouca água e comida
3


Ajude, minha ilha está inundando!
Diques podem impedir a inundação, mas é muito caro
A ilha de Toei está inundando porque o nível do mar está subindo
Toei
A solução é mudar para outro país
Tuvalu
Quando tem inundação, o mar invade as casas e mata as plantações


Sobrevivência na Floresta
Desmatar a Amazônia é ruim para o mungo todo. Menos árvores = mens oxigênio. Matar árvores contribui para o aquecimento global
Nos arredores da aldeia não tem mais muitas árvores. Fazendeiros derrubam as árvores para plantar soja e criar gado Tem pouca floresta para caçar
Brasil
Tepkatsie
Fazendeiros colocam muito veneno nas plantações e o veneno chega ma água do rio

Appendix 4 - Quiz Climate Change

From 1 to 6 (extra facts), from 7 to 10 (recall questions from the lecture)

1. Global warming is caused only by natural events:

A. Yes
B. No

2. Which country pollutes the most?

A. USA
B. India
C. China
D. England

3. How many deaths per year are caused by climate change according to the World Health Organization?

A. 1500
B. 10.500
C. 50.000
D. 150.000

4. How long does it take for CO2 gases to disperse at the atmosphere?

A. 100 years
B. 50 years
C.10 years
D. 1 year

5. How many species are at risk of being extinct in the Amazon rainforest?

A. 63 species
B. 633 species
C. 1633 species
D. 2633 species

6. Half of the world's rainforests have already been lost:

A. Yes
B. No

7. What can happen to Toei's island (Tuvalu) because of climate change?

A. The Island will be flooded
B. The rising sea water will destroy the land of the peasants
C. They will have to move to another place
D. All of the above

8. Because of global warming Jeremy's igloo smells faster:

A. Yes
B. No

9. In Ethiopia, streams and lakes are getting dryer and dryer. Which of these consequences for Halima is NOT true?

A. Halima has to walk more hours to find water
B. Halima is afraid of war in the region she lives
C. Halima has more time to go to school
D. Halima sometimes doesn't go school to help her family to find water

10. Using bike help to reduce greenhouse gases:

A. Yes
B. No