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MAKERBOX: INTRODUCING A LOW THRESHOLD MAKER EXPERIENCE FOR EVERYONE – AN ONLINE FACILITATION PLATFORM FOR PROBLEM BASED PROJECTS

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Abstract

This paper presents an online facilitation platform for project based education workshops, where the task formulations and solution methodology is based on engineering design methods. As design engineers, we are trained to see failure as lesson for future improvement and learn to identify the underlying cause for a problem. We want to contribute to the educational system, and expose children to design and decision-making problems before they reach college. We are also inspired by the maker communities around the world, and the great work they do towards inspiring and educating the engineers and designers of tomorrow. Most of the learning activities this community offers, is however based on step-by-step tutorials. In addition to the skills such projects train, we would like to add an element of ill-structured problems. The need for this perspective has been confirmed by teachers and maker-associations in our community. As a result, we present the Makerbox, an online facilitation platform for project based workshops. Usable by teachers and other engaged organisers. The paper also presents and discusses results from pilot tests exploring how the projects should be presented.

Keywords: Design education, Education, Social responsibility, Creative confidence, Problem based

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1 INTRODUCTION

Lately, there has been a global rebirth of the maker community; dedicated to inspire, educate and create a foundation of collaboration for further improvements. The Internet has played a vital part in bringing people together, and removing the borders for international collaboration between professionals and hobbyists. Getting started with making, is however not straightforward, despite an abundance of readily available resources. We believe that many children do not see an easy way to get started with projects, or they may feel discouraged because they are afraid of failing. This is where the engineering design community can contribute. The methods used to teach students at the university, prepare them to learn to cope with failure and see it as a lesson that brings them forwards. As the ever so wise Alfred says to Bruce Wayne, before he becomes a crime fighting Batman: "Why do we fall Bruce? So we can learn to pick ourselves up!". This is where the Makerbox© comes in. We wish to suggest it as the basis for an educational platform founded on core design methods and verified needs of educators and the maker community. It is designed to empower teachers and others to let young children creatively engage in practical problem solving activities without predefined step-by-step solutions. The need for access to such activities has been verified by several educators and maker-oriented people in our region. By creating a platform that has extremely low implementation costs, and that is easy to use for both teachers and students, we wish to jump-start the education of problem solving and design capabilities of the visionaries, designers, and engineers of tomorrow.

2 THEORY

Creative confidence is an aspect that has received quite a bit of focus within education at the university level, particularly within the field of engineering design (Davies, 2000; Laws, 2002). To become a practitioner confident in solving expected challenges, this aspect is an important personal trait. Creative confidence is derived from Bandura's (Bandura, 1997) idea of self-efficacy, where a person's belief in his/her abilities will affect the choices this person makes in the future. Where creative confidence addresses a person's creative abilities, the concept of self-efficacy can be applied to all aspects in life.

The pedagogical community has been talking about active learning for quite a while, giving it different names. A well-known version is "problem-based-learning", PBL. Which has been implemented in both medical education as well as in technological educations. PBL methodology sees the student as the focal point, and is designed to allow the student to act as a crucial decision-maker in his/her education. The intent of PBL is to train students to be independent and reflective problem-solvers with the ability to assess a problem and choose the appropriate path towards solving it. This includes defining the task at hand, choosing the best method to solve it, and through analysis discover what knowledge they need to acquire in order to reach a solution (Kolmos, 1996).

There is agreement among the design community that problem-solving is a skill which is both difficult to teach, and important to learn (Lehmann et al., 2008; Schmidt, 1983). Ambrose (2010), explains that attaining mastery is one of seven important aspects related to education. A second element is the importance of teaching the students to be self-directed learners. In respect of both these topics, choosing the appropriate challenge for students at any level is seen as important. Solution methods, prerequisites and learning outcomes differ greatly depending on what type of problem is at hand. Jonassen (2000) attempts to make the process of defining and creating problem-solving tasks easier by providing a structured overview of eleven different types of problems and what it takes to solve them.

Among the eleven problem types, many are already implemented to a large degree in schools. However, as we aim to educate our children to become self-directed and able to define their own solutions. It seems fitting to implement more a) design problems and b) decision making problems in the activities they are subjected to. The perspective taken is that design and decision making goes hand in hand, since the first is related to creating options, whilst the second narrows down; eventually reaching the best possible solution for a given situation.

The work described in this paper will continue to be motivated by the concept of creative confidence. However, it is argued that the methods and activities targeted at university design engineers can be adopted to inspire learning activities for school children. The proposed ideas are inspired by new-product development methods like the wayfaring model (Steinert and Leifer, 2012) and design thinking elements such as; bias towards action, show - don't tell, and prototype (build) to learn, as summarized by (Leifer and Steinert, 2011). For the purposes of this work, these methods have been condensed down to the design-build-test cycle (Gerstenberg et al., 2015) (see Figure 1).

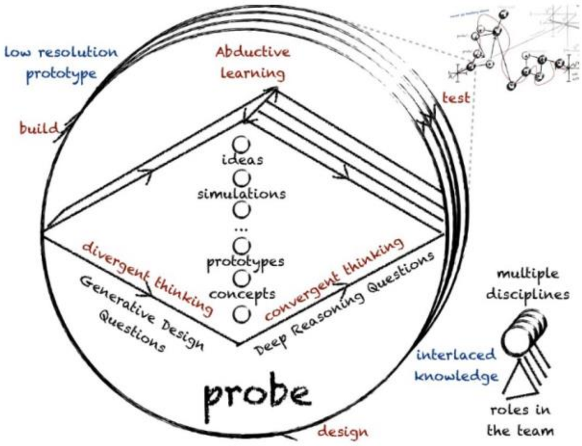

Figure 1. The design-build-test cycle, often used as an iteration step in development. Figure taken from (Gerstenberg et al., 2015)

As a motivational mechanism, some elements of gamification can be used to drive the work forward. By using game-based tools like points, high scores and competition to promote learning and solve problems, gamification can yield better attitudes towards learning than traditional methods (Kapp, 2012), and can give strong, positive effects, compared to traditional teaching, in cognitive gains and attitude (Vogel et al., 2006).

3 MAKERBOX ©

The Makerbox is an online facilitation platform for problem based education which provides a task interface for teachers and students. It is designed to be used in problem solving workshops, where students explore design tasks. Additionally, elements of decision making and strategic thinking are introduced through gamification. Students work in teams and are required to design, build and test their creations to complete the tasks given in the workshop. When the students have created a satisfying solution, a facilitator approves the task as complete and the team scores points. All teams can see the local scoreboard, and attempt to reach the top. Points vary between the tasks depending on difficulty and available time.

Figure 2. The Makerbox home-page

A workshop is an organized session in which the Makerbox is utilized as a framework for the learning experience. These can be arranged in classrooms, maker spaces or other venues where computers, as well as the required building materials are available. The people involved are the facilitator and the participants. The participants compete to be the best problem solvers under supervision of the facilitator.

Workshop organization is done by the facilitator prior to the student's arrival. Preparations are done by selecting a set of tasks from the Makerbox task database (Figure 3), and gathering the tools and materials needed. Material and tool requirements for the tasks is kept at a minimum to make the facilitation job easy, and to move the focus of the tasks away from fiddling and over to designing, building and testing. Makerbox was initially designed as a tool for teachers, but it could also be useful for maker communities or other extracurricular activities. For the remainder of the paper, it will be assumed that the facilitator role is filled by a teacher.

3.1 Facilitator interface

The teacher is the facilitator of a workshop and initiates, facilitates and finishes the workshop. When initiating a workshop, the teacher must choose tasks from the online repository that are appropriate for the students' abilities. The tasks must be chosen to fit the available amount of time, as each task has an associated time limit that will affect the overall time for the workshop. Tasks can be added to the workshop through the task selection page (Figure 3). Each task is presented on the selection page with some information, like difficulty, time usage and points, and it is possible to search for tasks. The teacher can find more detailed information by opening the task cards (Figure 7) and the tasks can be added to the workshop.

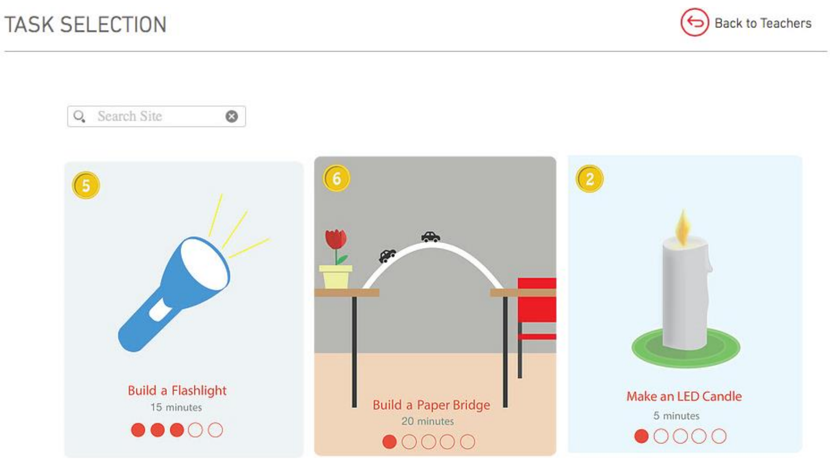

Figure 3. Teacher task library

When the workshop is completed, a summary of required materials and tools for the chosen tasks is shown (Figure 4). The goal of the tasks is to enable rapid prototyping and iterations of design-build-test cycles, hence the simplicity of materials used.
On completion of a challenge, the teacher evaluates the solution, if it satisfies the task, marks it as complete through the teacher interface (Figure 5). Points are then assigned to the student team. Until a good routine for teacher training is developed, the design evaluation is based on his/her understanding of what a sufficient solution looks like. The teacher interface allows the teacher to quickly see how each team is doing and how many tasks they have completed.

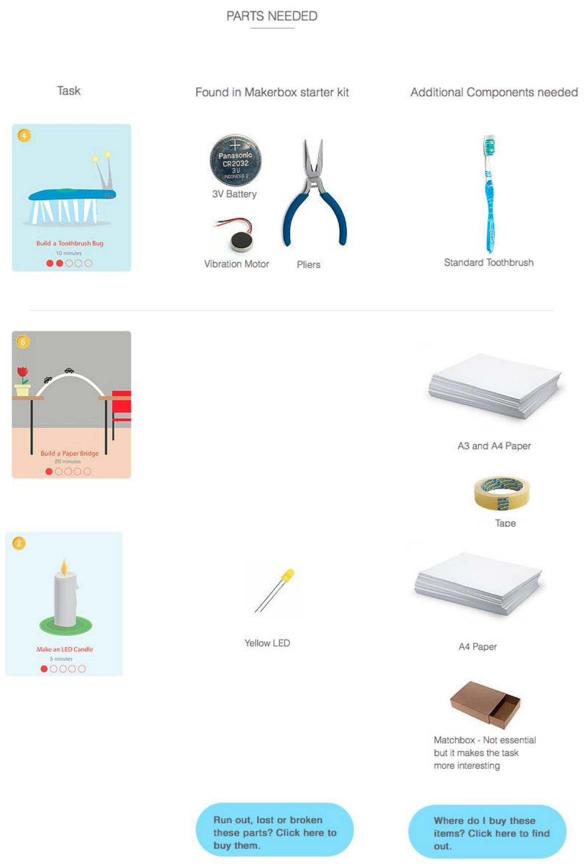

Figure 4. Parts and materials needed, as summarized for the facilitator

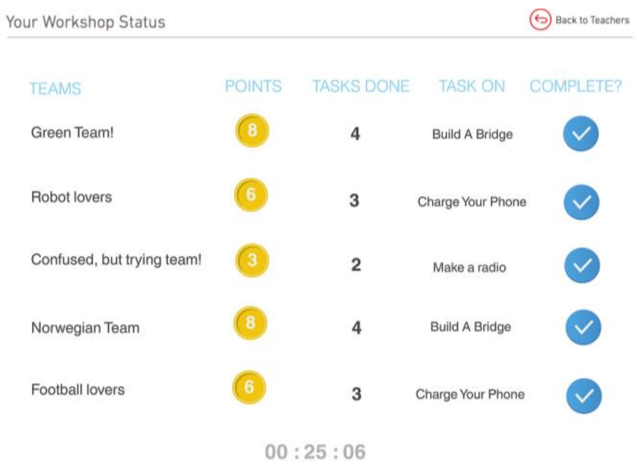

Figure 5. Teacher interface during workshop

3.2 Student interface

When joining a problem-solving workshop, students are divided into groups and are presented with the student interface. Figure 6 displays the available tasks in the workshop. Each task displays information about the difficulty, estimated time usage and points available for completing the task. As the timer starts, the students must decide which task they will start solving. The only basis they have, to make their decision is; available time, and point value for each task. The internal factors expected to affect this decision is their self-confidence, as well as a strategic choice of whether to attempt a difficult or easier task first.

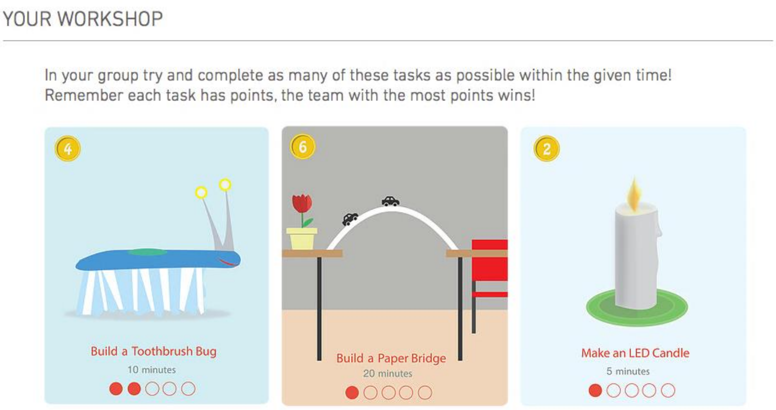

Figure 6. Workshop with 3 tasks

After a task is selected, the students are presented with a task card as seen in Figure 7. The task card has a short description of the problem that should be solved, and the materials that are available for completing the task. If the students are stuck, or want to solve the task faster, there are hints available. The hints can be chosen, but will lead to a reduction in the point value of the task. To inspire the students to work quickly, the record time of the challenge is shown in the bottom left.

Figure 7. Task description example

The students are expected to work with the materials and discover the possibilities they offer, without input from the teacher. They can prototype until they are confident to test the design. Testing implies showing the construction to the teacher, and get it approved or rejected.

4 PILOT EXPERIMENT

While developing the Makerbox platform, two early stage pilot tests were conducted. The first involved 5 students in middle school (15 years of age). The second test was conducted with 54 primary school students (12-13 years of age). Results from the first pilot test, showed that the students tended to fixate their designs towards the illustrations provided in the task cards. This also seemed to slow them down, hence we formulated a hypothesis: An increased level of details in imagery in task descriptions will decrease time efficiency and limit the solution space.

Our assumption is that, when students are provided with a graphical example, they believe this to be the optimal solution. Hence, they wish to replicate the example to as high a degree as possible. Thereby spending more time on checking the example and recreating all its features. Variation in the solution space is also expected to be affected by details in the example. If true, features evident in the example imagery will be recurring more often among students exposed to these. An experiment was set up to test the effects of time usage and design fixation.

4.1 Test setup

Further testing was conducted at a primary school with students aged 12-13. Two Makerbox members acted as facilitators of the workshop. The activity took place in a classroom, in sessions with four (4) groups at a time, with three (3) students in each group. In total 19 groups solved the tasks, over five (5) sessions. The team sizes were set to three (3) to get teams which could make quick decisions and not be too big for the task. It is believed that a trio can be fast with decisions, as there can be no even vote (Wilde, 2008). All teams in the same session had the same stimuli, and they were assigned a corner of the room each, giving them sufficient space for prototyping and testing, without easily seeing the work of other teams. Communication between the teams were not allowed. The task cards presented clear criteria the solution had to fulfil in order to be accepted. If the students attempted to ask the facilitator for hints, or if they tried to ask for help, they were simply told to try themselves and see what happened. The independent variable of the experiment is variation in the task description, 1) text only, 2) text and illustration, 3) text and a photo, see Figures 8-10. The images used in task 2) and 3) were made to introduce unintuitive features, which were assumed to be less likely to appear among the student's solutions, if the participants were not exposed to the images. In conducting this experiment, there are two deviations from the operating procedure described above. Firstly, a variation in what type of stimuli the groups get. This is the independent variable in the experiment. Secondly, the elements of gamification are removed. There is no scoreboard or record times included in the tasks. Otherwise the workflow is as described above.

Figure 8. Independent variables, 1) text only, 2) illustration and text, 3) photo and text. The task description translates to: Using paper and tape, make something which holds a cell phone 10cm above the desk

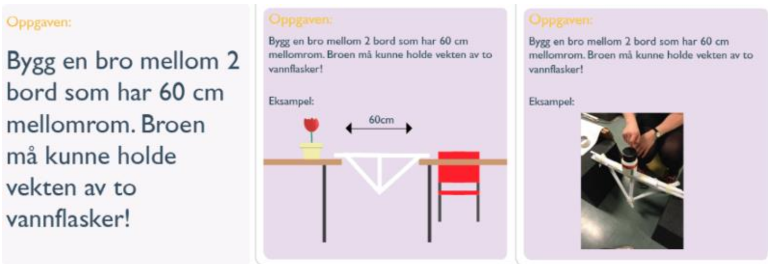

Figure 9. Independent variables, 1) text only, 2) illustration and text, 3) photo and text. The task description translates to: Build a bridge between two tables with a 60cm gap. The bridge must be able to support two bottles of water

Figure 10. Independent variables, 1) text only, 2) illustration and text, 3) photo and text. The task description translates to: Use the available parts to make something which emits light and can be used at a torch

There were 3 tasks to be solved. One bridge-building task, one task to build a torch and one task to build a phone stand. The available materials were paper and tape for the bridge and phone stand, and the torch also had an LED and a battery.

4.2 Results

The test results are analysed as a combination of measured time usage, and observations made by the facilitators during the test workshop. Limited solid conclusions can be drawn based on this data, but we have gained experiences we are confident will improve the quality of the Makerbox platform. The text based task seems favourable, as it results in quicker task completions. When it comes to design fixation, it is harder to say something definite. Due to interpersonal difficulties in two groups, we have removed those groups from the data analysis.

4.2.1 Design fixation effects – solution feature variation

Introducing photographs in the tasks affected the observed solutions and the behaviour of the students. Students were observed to study the photographs, pointing to features and replicating them in their own solutions. Some groups replicated the example photograph down to every detail, while others replicated only the major features. This focus on details is observed to affect time usage, as the example-features could be hard to replicate, without necessarily representing an optimal solution.

The same effects were not observed to the same degree when presenting the tasks with illustrations, although some fixation towards the example-features were still evident. For example, no torches with an orthogonal light were seen in the groups who only got text based tasks, while in the groups with illustrations and photographs, they were frequent.

With more visible details, the groups reported to “have a feeling” that the presented solution in the photograph felt like “the best solution” or simply “it felt right”. This resulted in them trying to recreate features observed in the pictures and not testing their design before some or all of these features were completed.

4.2.2 Time effects

We performed statistical analysis on the total time usage between the different task stimuli. The results are shown in Figure 11. As we can see, the groups who got photography's as stimuli were significantly slower in solving their tasks. Among the three tasks, especially the bridge-building task contributed to a lot of the time difference. The analysis was done using independent t-tests in IBM SPSS (N = 17, n-text = 5, n-illustration = 4, n-photo = 8).

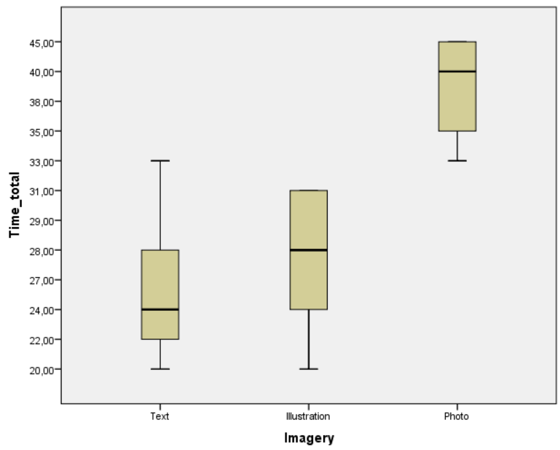

Figure 11. Box plot showing total design time depending on task stimuli. The y-axis shows the total time used for all three tasks, bridge, LED-torch, and phone stand

As mentioned above, observations during the workshop explain the differences in time usage based on the student's perception that they had to replicate the example. Difference in the mean time between text based and illustration based tasks is not significantly different, even though a small increase in time is seen in the group with illustrations.

5 EXPERIENCES AND EVALUATION

During testing of the Makerbox platform, the feedback has been positive. Students were excited by the lack of boundaries and the freedom of the problem based tasks. Motivational elements are expressed as being able to explore their own ideas, and not being limited. They developed solutions and structures

that may seem unintuitive for those with engineering education, while still solving the problems beautifully (Figure 12).
It was observed that the inventiveness and creativeness that is displayed by the students may be inhibited by the introduction of images in the tasks. For some groups, the focus seems to shift away from the problem and onto specific features when an example is presented. We propose that text-based problems may be optimal for the future development of the Makerbox. This is actually an advantage, as it will make it easier for the community to contribute with tasks without having to create illustrations or take good photographs. The difficulty of writing clear task descriptions does however remain, defining an understandable task without limiting the solution-space.
The maker-movement has had a wonderful effect in society by inspiring us to rediscover the joy of creating and making, but most of the projects they promote are distributed as step-by-step type tutorials. This is great for training skills in specific domains, but this paper shows that tasks without instructions also engage and inspire young creators. Development of the Makerbox has been done in cooperation with the local maker-community.

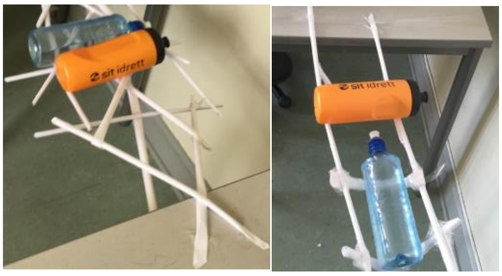

Figure 12. Two bridges of different designs

Makerbox seeks to create a teaching environment that should cost little to implement and operate. Our desire is that the platform can be implemented in existing makerspaces or classrooms and utilize the tools and materials that are already present. While classrooms often are sparsely equipped, they usually have access to common office supplies like paper, tape and scissors. Makerspaces may have much more advanced equipment, like electronics, microcontrollers, 3D-printers and more, and thus the tasks performed there can be more advanced. The aim with Makerbox was always to facilitate activities with a low threshold, focusing on enhancing the creative confidence of young children.

5.1 Teachers and implementation of the Makerbox

Teachers are used to being sought out by students for help or assistance. The goal of Makerbox is to let students explore their own problem solving capabilities. However, when teachers are present, they tend to assist the students by giving them hints, showing them what to do or how to build. This goes against the goal of the platform, and teachers may have to be taught how to facilitate without interfering with the project process.
Teachers have also expressed that they need to grade the students over the course of the school year, and they requested a way to incorporate grading into the Makerbox for easier implementation into their classes. In Norway, teachers are also required to justify each class activity with a basis in governmental curriculum plans. Through expanding the task repository, workshop creation can be customized to fit certain national learning goals or objectives.

5.1.1 Scalability

Makerbox was designed, developed and tested by the authors as part of a student team project at Norwegian University of Science and Technology (NTNU). The platform is not publicly available at this time, our future vision is that educators and maker enthusiasts around the world will be able to use the platform. Further development of tasks, will be done with school learning goals and curriculum plans in mind. Testing will also expand to university level with subjects ranging from economics to engineering. The first step towards achieving this, is to develop a well-implemented web page. The web page requires expanded possibilities for data logging and real time handling of workshops, tasks etc. Some features presented in this paper are not fully functional and/or automatic yet.
Firstly, implementation of all features on the Makerbox website will be completed. This will allow us to implement the system on a local basis, through local schools and maker-associations. Another goal is

to make it possible for all users to contribute to the development of a task database. This requires a background system which can handle the community we wish to surround the platform. The result should be that anyone interested in contributing can do so by using a task creation template, see Figure 13. There are many enthusiastic communities and individuals who have great ideas for tasks and problems to be solved. If these can be gathered in Makerbox, the platform will grow better and better.

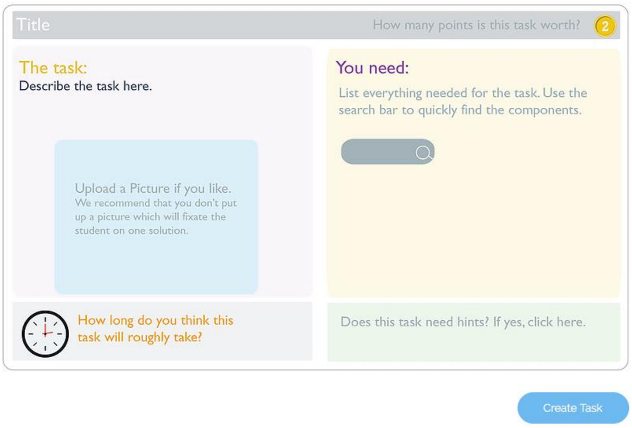

Figure 13. Template for submission of tasks

With these improvements in place, we believe the only remaining ingredient for success with the Makerbox, is global interest and engagement.

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