AC 2007-2003: UNDERWATER LEGO ROBOTICS: TESTING, EVALUATION & REDESIGN

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Underwater Lego Robotics: Testing, Evaluation & Redesign

Abstract

In this study, underwater robotics using LEGO was used to analyze the testing, evaluation and redesign phases of the engineering design process. A group of all male participants of a summer camp at Tufts University, ranging in age from 10 - 13 were instructed to first build a boat; then modify their boat to become a submersible. The activity required the students to test their creations in a small pool away from the building area in order to reinforce the iterative nature of testing and redesign. Each student's process was mapped out in time and with a flow diagram to vividly illustrate his individual process. Through this analysis, the study supplies an example of how underwater robotics can be used to integrate the engineering design process with related science topics in the classroom.

Introduction

Underwater robotics is an up and coming field of study in engineering. This area is being studied not only for uses in scientific exploration[1], but also for uses in the classroom[2]. With a broad range of topics involved in underwater robotics, it makes related activities ideal for teaching multiple concepts, while supplying a great context for hands-on activities. This study focuses specifically on one contained experiment involving underwater robotics and students ranging in age from 10 - 13. In this experiment, students' behaviors toward testing their designs, evaluating their results, communicating with others around them (students and counselors), and redesigning their underwater robots was analyzed to establish an initial hypothesis about the use of underwater robotics. This paper reports on the results of integrating science concepts and the engineering design process into an underwater robotics design challenge.

Theoretical Framework

The underwater robot design challenge is a hands-on, student-centered activity designed within the framework of constructivism. Piaget, a pioneer in developmental psychology, describes children as active builders of knowledge who, like scientists, discover and inquire as they learn new ideas[3]. This idea that students build knowledge is the backbone of constructivism. Methods of constructivism allow for very open inquiries among students and let them explore and learn from the environment around them and build the knowledge on their own. The underwater robot design challenge takes advantage of constructivist methods where the students are given an open-ended challenge to design and construct a LEGO-based underwater robot. This challenge also includes many of the ideas of constructionism[4] given that the students will construct actual artifacts as they engage in the learning process. The major tenets of constructionism are also incorporated as the students will be able to design and create a personally meaningful project, discover and learn powerful ideas, and then reflect upon their learning. A number of researchers have successfully implemented such a framework while using the LEGO toolset [5-7]. These sorts of methods will be used as the students design and build their LEGO submersible vehicles.

Educational Objectives

The underwater robot design challenge incorporates the engineering design process as defined by the Massachusetts Department of Education[8] with related science concepts. Figure 1 displays the eight steps of the engineering design process. The last three steps are highlighted to illustrate that the researchers are most interested with the students' behaviors and approaches as they test and redesign their robots. The science topics included in this design challenge include:

1. *buoyancy* - the tendency or capacity to remain afloat in a liquid or rise in air or gas; the upward force that a fluid exerts on an object less dense than itself
2. *propulsion* - the process of driving or propelling
3. *balance* - a state of equilibrium or parity characterized by cancellation of all forces by equal opposing forces
4. *torque* - the moment of a force; the measure of a force's tendency to produce torsion and rotation about an axis, equal to the vector product of the radius vector from the axis of rotation to the point of application of the force and the force vector.

These concepts are never formally taught to the students in a lecture format, instead they are included as hands-on, experiential learning objectives.

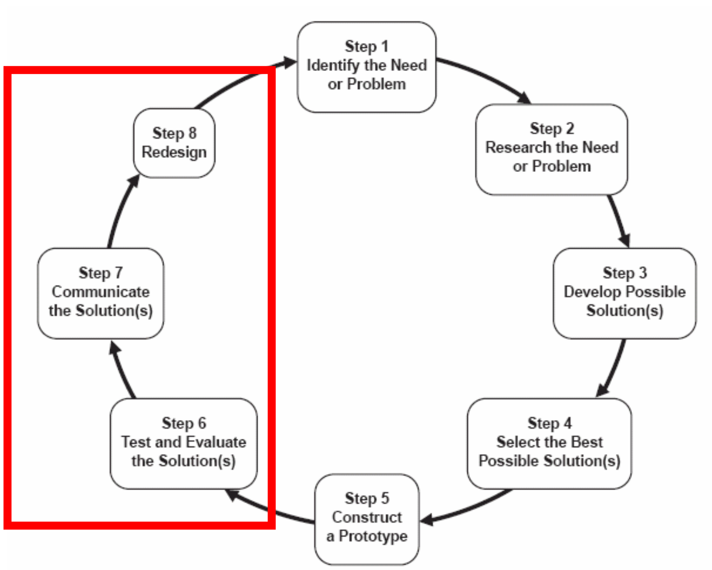


Figure 1: The engineering design process (Massachusetts DOE, 2006).

The Approach

The incorporation of the engineering design process with these science topics is not typical to a traditional classroom. Typical existing practices are subject to teachers' teaching styles and the textbooks, as well as the syllabus of the particular class the material is focusing on[9]. In general, introductory physics classes that would address underwater-related topics do not aim to give students a deep understanding of the concepts; rather they go through many concepts, sometimes superficially, to cover as much material as possible so as to 'best prepare a future physicist'[10]. Rarely are connections made to real life uses of these particular concepts resulting in a very disconnected view of how these concepts transfer. Related labs for these topics are typically very structured with little cushion allowed for experimentation with the concepts (cook book laboratories). Lastly, the topics themselves are often taught too late to the students[11]. Integration of the material, even if just for the students to get a feel for it early on in school, is vital to a student's understanding and comfort with the topic later on.

The focus of this design project is to take advantage of learning through an inquiry-based approach[12]. For this approach, students were introduced to the concepts through an open-ended, hands-on activity with three tasks:

1. Build a boat capable of floating
2. Make the boat move across the top of the water (requiring programming of the robot)
3. Make the boat become a submarine capable of maneuvering under the water

The students participated in this activity at the Tufts University LEGO Summer Camp. The camp is designed to be a completely constructivist learning environment[13]. The aim of the one week summer camp program is to have students currently in grades 4-9 (between the ages of 10-13) participate in both individual and small-team design projects in order to foster an understanding of the engineering design process. Several engineering challenges are presented throughout the week. Students use LEGO and ROBOLAB software as they design, build, and program robotic creations. Each child is encouraged to work within his (not by design, the entire camp was male) own abilities and explore new approaches and understandings along the way. Camp counselors consisting of Center for Engineering Educational Outreach staff and Tufts University undergraduate and graduate engineering students supervise and assist the students. The underwater robot design challenge was the final challenge of the summer session. The activity was presented as an extension of the building and programming skills they had learned throughout the week. They were given approximately three and a half hours to complete their design.

Research Methods

Data Collection & Analysis

Each student's testing, evaluation and redesign was observed, recorded and documented via time stamping, noted actions, and marked successes and failures. These data were collected by multiple observers.

Collected data were organized and converted into two analysis tools: timelines (see Appendix I) and flow charts (see Appendix II). The timelines were plotted using time stamping in order to visually see how students managed and used their available time. Figure 2 is an example of one student's timeline.

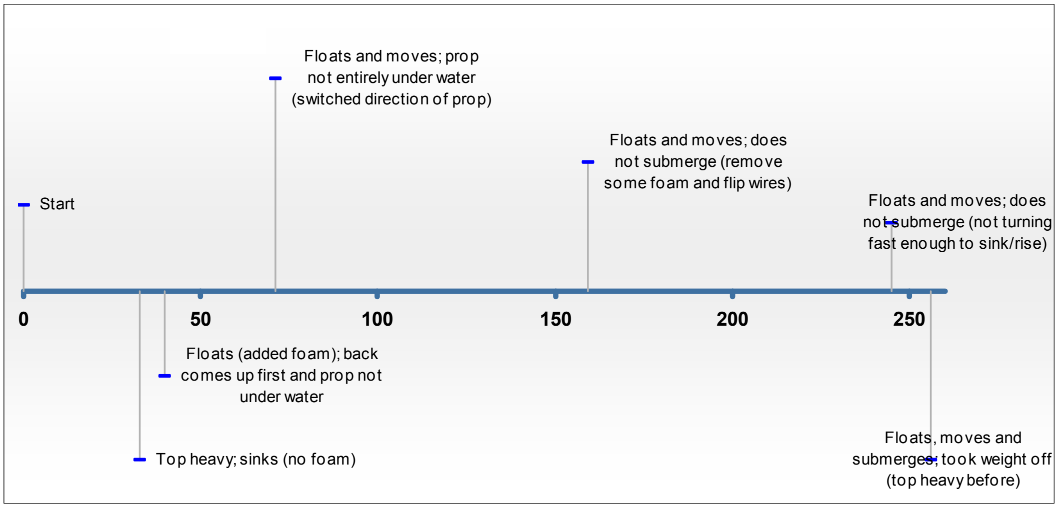
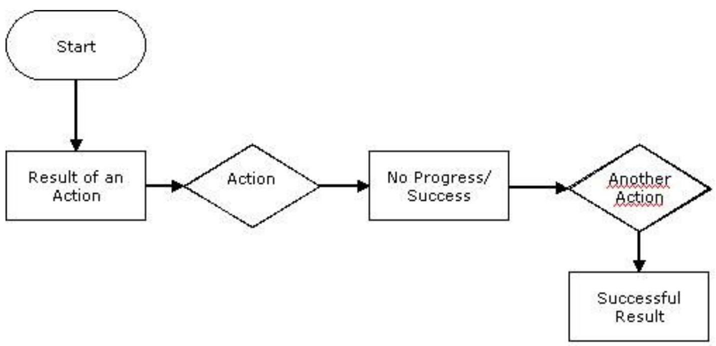


Figure 2: Example timeline

Flow charts were used to visualize how students' actions and results proceeded throughout the testing, evaluation and redesign processes[14]. The following example in Figure 3 shows a possible flow.



Rectangle: result of an action

Diamond: an action

Circle: accomplished all goals

Horizontal movement: no progress/success

Vertical movement: success

Figure 3: Example flow chart

Students were also classified, based on their performance, using a 4-level classification scale:

Level 1: works within the assignment
Level 2: works within the assignment while slightly expanding the context
Level 3: able to express what can be imagined by the available pieces
Level 4: able to build off imagination and does not limit themselves by available pieces (constructs abstract creations)

Results

Given the before mentioned tasks, only 1 of 13 students accomplished the 3 tasks in the given amount of time (3.5 hours). All students accomplished at least the first 2 tasks suggesting that the given amount of time available for the students was not adequate. In general each student built, tested, evaluated, communicated with other students and counselors, and re-designed their boats to succeed in accomplishing the first two tasks. Each student's creation was a unique answer to the problem (Figure 4).

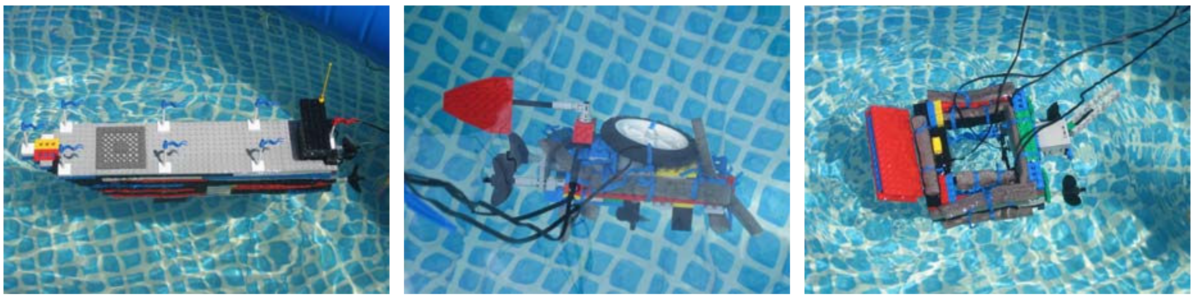


Figure 4: Example boats/submersibles built by the students

From the student classifications it was determined that out of 13 students (**Table I**), 6 were at Level 1, 2 were at Level 2, 4 were at Level 3 and 1 was at Level 4*.

Table I: Number of students within each classification level.

Level 1	Level 2	Level 3	Level 4
6	2	4	1

In general, Level 1 students spent a lot of time making quick thoughtless changes to their boats. Many eventually became frustrated with their continual failure, but eventually sat down and succeeded with help from counselors or other students.

Level 2 students typically achieved early success resulting in a drive to design something more advanced (not necessarily better) or more highly suitable to accomplish all three tasks.

Level 3 students attempted to build something extravagant in order to better the other students. There thought process proceeded as planned by taking time, contemplating decisions, allocating time appropriately, and achieving success.

The Level 4 student hypothesized and contemplated for an extended period of time in order to create something that would theoretically accomplish all the goals with very little testing. He perhaps over thought his design a bit and did not allocate his time appropriately to allow for sufficient testing.

* Refer to Appendices I & II for example timelines and flowcharts for each level.

Age was not a factor in that there was no pattern as to the younger students being labeled as lower level students; however, it was easy to identify which students played more often with LEGO pieces at home on a daily basis. Students were not interviewed so this observation is merely a result of the researchers' informal discussions with the participants.

Discussion

From the results it was shown that the new underwater activity approach was a useful tool to introduce the engineering design process, buoyancy, propulsion, balance and torque to students between the ages of 10-13. Each student appeared to enjoy the activity and based on researcher observations learned a number of relevant concepts including:

- Weights make the boat sink
- Foam makes the boat float
- Motors need to be turning in the same direction for the boat to go straight
- Motors need to be equally spread about the center for the boat to turn easily
- Weight must be balanced so that the boat does not flip
- Gearing results in a more controlled boat

Without a control group looking at traditional teaching of these concepts, the full benefits of this activity cannot be stated outright; however, based on this confined experiment, the researchers hypothesize that the hands-on experience these participants received was beneficial to introducing related science concepts. Aspects that appear to be attributed to the success of this activity include the project being very connected to real-life, students ability to identify science concepts with a bit more ease when they were able to actually see it occurring, the ability to make the project personal with a sense of pride and possession, and a high level of communication between both students and counselors.

The disadvantages are that these approaches employ a less technical understanding of the concepts. At times, this approach can be difficult for teachers to teach such a lesson where students are working on their own and moving from testing station to work station (active chaos). These approaches also make it extremely difficult to assess the students since there is no real way to constitute what is right and wrong or good and bad in an environment with unlimited and unique viable solutions.

It is also important to discuss the effects of the learning environment in which the study was conducted. Because this study was done in a situation where students would not be assessed, there was no drive besides personal satisfaction and intrigue to elicit the students to accomplish any goals. In fact it was evident that a number of students once they accomplished the first 2 tasks were content with that achievement and decided to play with their creation rather than improve or attempt the third task. This, of course, would be a different scenario if this activity was infused into a classroom.

Conclusions

From this pilot research study it was shown that this constructionist approach[4] activity is a viable and possibly advantageous option for students to perform in order to gain a good understanding of the engineering design process along with the relevant science concepts incorporated with underwater robotics. This approach did lack a connection between the hands-on experience of the concepts and the technical definitions. Only using this method would not allow the students to effectively communicate and explore in depth the science behind their creations. They may also have difficulty transferring this knowledge to other applications. A suggested solution to this dilemma would be a curriculum, where students are introduced to the concepts and as a class inquire into the principles as they work hands-on.

The environment had a definite effect on how the students approached the activity. With no assessment there was no need to accomplish all 3 tasks. Yet all the students were able to achieve success for 2 of the 3 tasks based on personal drive and interest. The environment also promoted a high level of communication and teamwork without ill effects.

This study is not an exhaustive analysis of the benefits of this activity. The next step for this project will be to investigate the effectiveness of teaching this activity in a classroom environment and comparing it to a traditional classroom. Ideally, this activity would be something taught in a 3rd or 4th grade class. Prior to teaching this in a classroom, teachers must be trained in how to use the materials and how to proceed in performing this activity. Assessment of this activity will also have to be fabricated. Another longitudinal corollary to this activity would be analyzing these same students when they reach high school and how they approach learning physics after having experienced a number of the concepts earlier on in their education.

With the incorporation of such activities as the one presented here, which bridge the gaps between areas of study, ultimately, more can be learned through less activities resulting in more time for students and teachers to investigate science and math.

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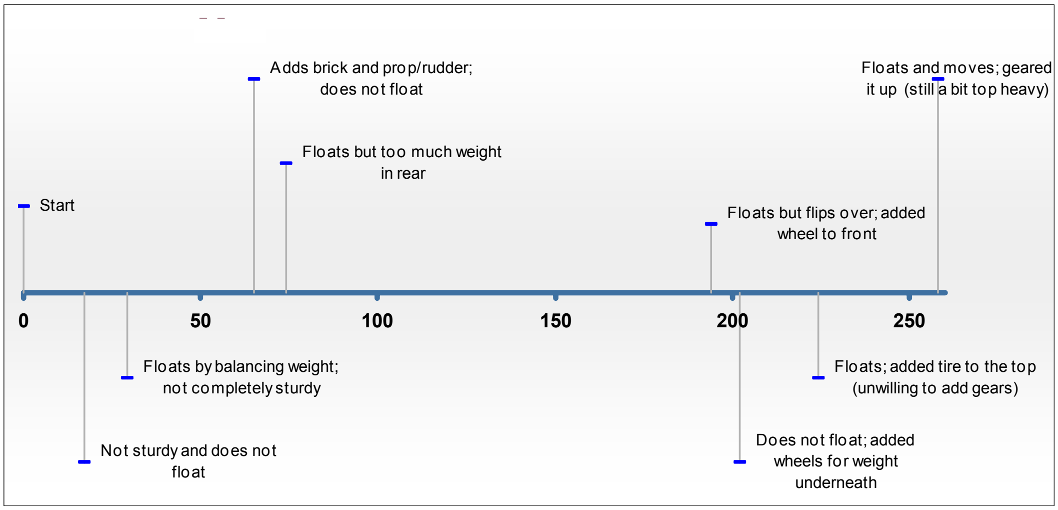
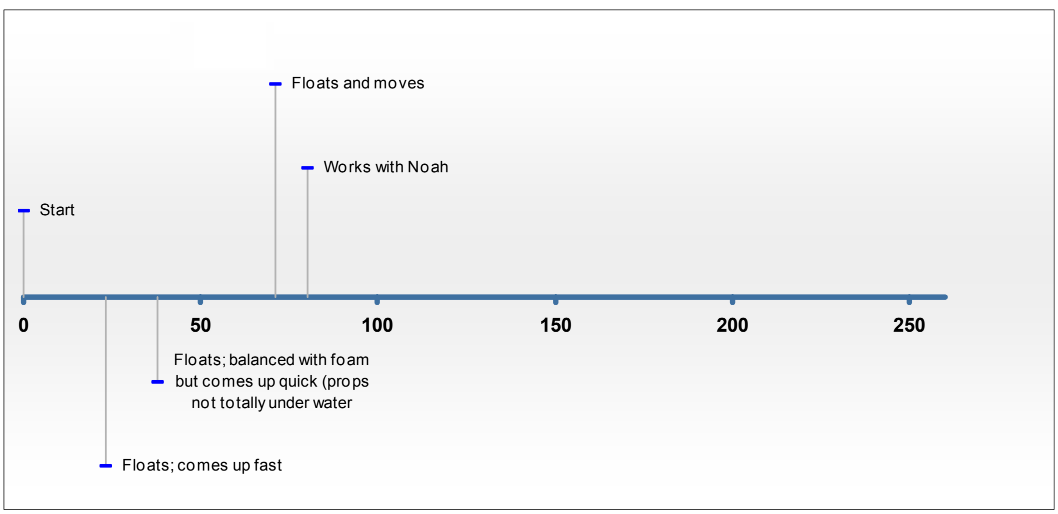
Appendix I: Timetables

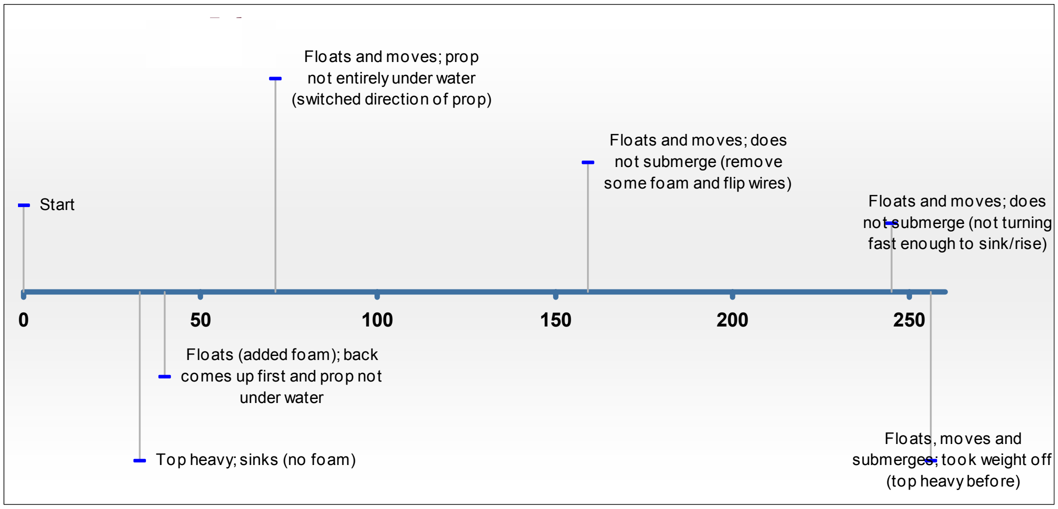
<u>Level 1</u>



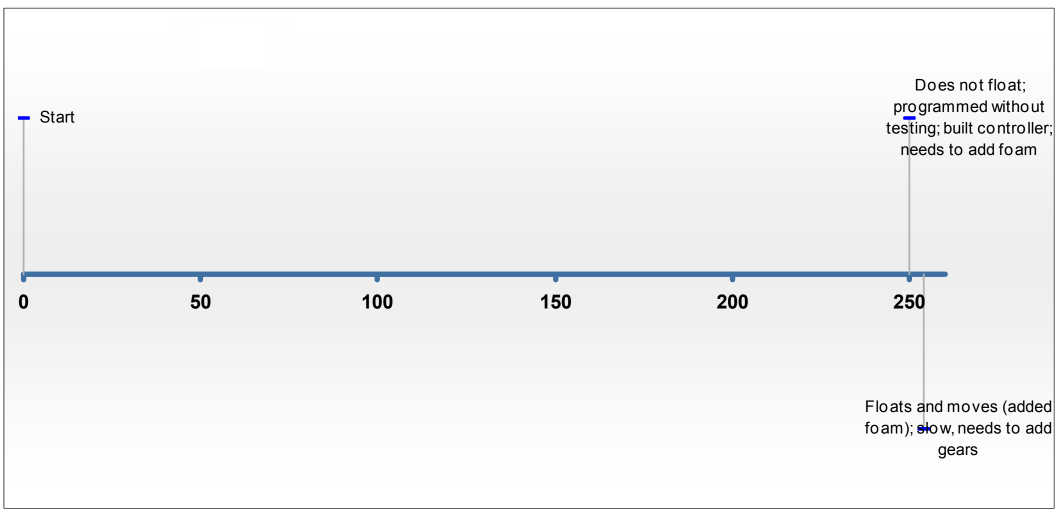
<u>Level 2</u>



Level 3

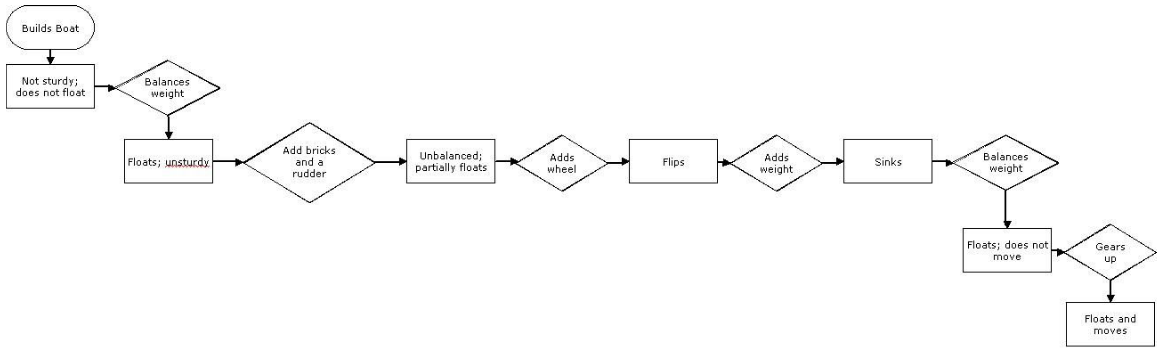


Level 4



Appendix II: Flow Charts

Level 1



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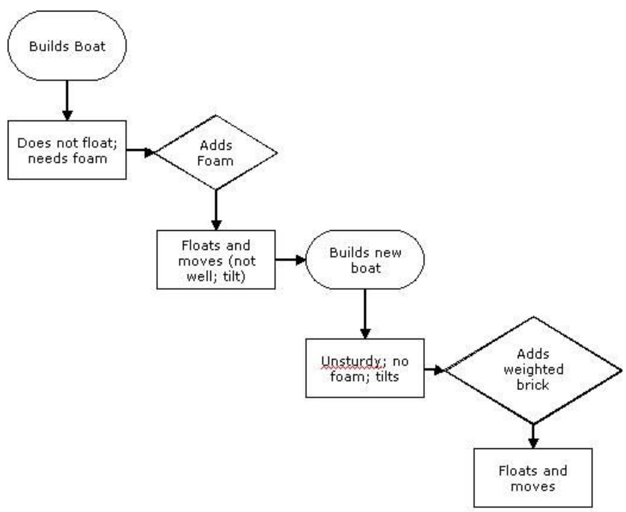

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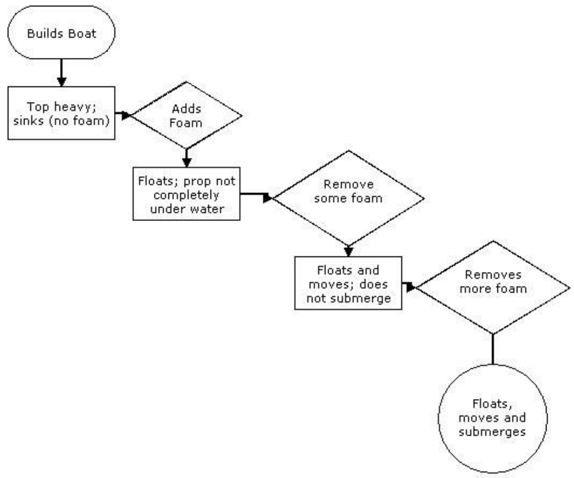

Level 4