Differential Student Engagement with Hands-on Activities
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Abstract
As part of a larger study in supplemental instruction, the authors developed and delivered five, one-hour supplemental learning experiences to a group of ~25 students over the course of the Fall quarter. Over the course of the five supplemental instruction periods, students (in groups of about 5) participated in a total of 17 hands-on activities, ranging in length from 5 to 20 minutes each. The primary objective of the hands-on activities conducted during the supplemental instruction periods was to emphasize pertinent concepts that students were learning about in a transport phenomena course. The motivation for the supplemental activities is to provide direct experience with very physical notions (e.g. conservation of mass, linear momentum, angular momentum, energy, etc.) that are covered in the class but with which many students may lack direct experience. The hands-on activities were developed to engage students in exploring the physical phenomena behind the concepts, and in this way to provide an improved context for their learning in the course. A secondary objective for the developed activities was to illustrate concepts with objects/activities that would be common to students own experiences to improve the perceived relevance to the students.

The student response was often counter to the anticipated interest level with flat responses where enthusiasm was expected and tremendous enthusiasm and exploration where mere participation was expected. No clear causal relationship between engagement and activity type was clear at the conclusion of the supplemental instruction. For example, why do students enthusiastically experiment with a toilet mounted on wheels to allow students to see its functionality, but show little interest in a similar example involving a bathroom sink on wheels? Why is a syringe (without needle) more exciting than a hair dryer? For planning future activities, understanding the factors affecting student receptivity will enable the authors to develop examples that are at once illuminating and engaging. In this presentation and the accompanying paper, the authors will report on their conclusions regarding the factors underlying student enthusiasm and engagement with the hands-on activities.

Key Words
Education Methods, Innovative Teaching Method
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Introduction
Many studies have made the causal link between student engagement and academic performance\cite{1-4}. In order to assist students through the challenging introductory course in the Rose-Hulman Institute of Technology Sophomore Curriculum, a series of 17 hands-on activities were performed by 25 students (divided into six self-selected groups) in five sessions over eight weeks. The Conservation and Accounting Principles course introduces Sophomores to conservation of mass, momentum (linear and angular), and energy as well as entropy accounting and is often challenging to students who have difficulty in connecting physical examples to the governing mathematical equations. Each of the 17 activities was designed to engage students but, as the authors found, the students involved the study found some activities much more engaging than others. A review of the activities and the associated student engagement level was undertaken in order to assist in the design of engaging hands-on activities in the future that might improve course learning\cite{1}.

The 17 hands-on activities were designed to illustrate specific conservation of mass, momentum, and energy. The motivation behind the majority of the activities was to explore the function of common devices (e.g. toilet, hair dryer) using the course conservation principles. Table 1 organizes the 17 activities into three categories (based on the instructor perceived student response to the activity): Engaging, neutral, and less than engaging. Engaging activities were ones in which students explored the activity on their own, beyond the scope of the defined activity, and usually involved the students asking leading questions of each other regarding the activity. This was most apparent by the dramatic rise of volume level in the room as students discussed the activity as well as their focus on the activity and could also be assessed by their attention focus on the activity\cite{4}. Neutral activities were ones in which the students explored the activity as defined by the instructors but without apparent gusto. Less than engaging activities were ones in which the student’s interest level and enthusiasm were both clearly low. Before discussing our hypotheses about the reasons for the observed outcome of these demonstrations, a brief description of each activity is in order.

Description of Activities
The first two sessions explored conservation of mass principles. In the first session, the ethanol/water demonstration illustrated the importance of conserving mass and not volume by the instructor mixing equal volumes of water and ethanol and showing the class that resulting volume was less than the combined original volumes. Next, a syringe was given to each team and they were asked to try to compress a volume of air and then a
volume of water to illustrate the difference between compressibility and incompressibility. The students were also asked to pull a volume of water into the syringe and see that none of the water would exit without pushing the plunger as no mass could flow in. A toilet and a sink were mounted onto movable bases and operated for class to illustrate mass flow systems.

<table>
<thead>
<tr>
<th>Engaging</th>
<th>Neutral</th>
<th>Less-than-engaging</th>
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<tbody>
<tr>
<td>Session 1</td>
<td>Syringe</td>
<td>Ethanol/Water</td>
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<td></td>
<td>Toilet</td>
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<td>Session 2</td>
<td>Multiple tank mass flow</td>
<td>Sink</td>
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<td>Salsa</td>
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<td>Session 3</td>
<td>Newton’s cradle</td>
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<td></td>
<td>Impulsive force in a bucket</td>
<td>Placemat pull- bowl</td>
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<td>Fan supporting balloon</td>
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<tr>
<td>Session 4</td>
<td>Placemat pull – glass</td>
<td>Brick on a skateboard</td>
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<td></td>
<td>Tipping due to force Tipping due to acceleration</td>
<td>PVC pipe</td>
</tr>
<tr>
<td>Session 5</td>
<td>Nerf™ dart gun</td>
<td>Hair dryer</td>
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<tr>
<td></td>
<td>Dice</td>
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</tbody>
</table>

Table 1: Activities and their associated engagement levels

During the next session, a three tank system was made available, with each tank at a different height and connected by hoses. The water was transported from the lowest tank to the highest by a high flow rate aquarium pump and flowed into an intermediate tank before ultimately flowing to the collection tank. A valve on the intermediate tank allowed students to control the flow to the collection tank in order to achieve steady-state operation. Finally, species accounting was demonstrated by giving students components of a salsa recipe and having them compute the weights of individual components after weighing the combination.

The third session explored impulsive forces and conservation of linear momentum. It started with students exploring surface friction and impulsive forces by pulling a placemat from under a bowl without removing the bowl as well (based on a classic magic trick). They then used Newton’s cradle to explore conservation of linear momentum. Next, an air filled balloon attached to, and held aloft by, a vertically oriented fan was used to illustrate transport of linear momentum with mass flow. Students then measured the effects of different padding materials on reduction of peak impulsive forces generated by dropping a weight into a bucket (with the padding placed at the bottom of the bucket). Finally, a brick sliding on an accelerated skateboard illustrated sliding friction and acceleration.
The fourth session explored conservation of angular momentum and began by showing tipping of a cup due to a placemat pulled from beneath it (in contrast with the previous bowl example). A length of 1” diameter PVC tubing with attached handles demonstrated moment couples and application of moments. For the next two activities, student used the skateboard from session three to illustrate tipping of objects due to both forces (contacting a tube standing on the skateboard as it passed under and obstruction) and accelerations (the skateboard being accelerated by an external force).

The fifth and final session involved conservation of energy related activities. Students were given a hairdryer and measured both the velocity and temperature of its output flow and compared it to the energy input via electricity, which also allowed for introduction of mechanical efficiency. A Nerf™ dart gun was aimed vertically and used to illustrate conversion of spring potential energy to kinetic energy and then to gravitational potential energy. To make the potential energy increase of the Nerf™ darts more easily measurable, it was necessary to increase the weight of the dart, so a standard six-sided die was attached to the suction cup on the dart. It is included in Table 1, even though it is not an activity, due to the (surprising) enthusiasm shown for it by the students. The sound of dice hitting the lab tables was almost constant throughout the session.

**Observations**

Some of the activities that students found engaging were expected, such as the toilet or the Nerf™ dart gun while others, like the multiple-tank mass flow system or the impulsive force in a bucket, were a complete surprise. It was expected that the most interest would be generated by unusual equipment, such as the toilet but the equally strange sink-on-wheels did not generate the expected interest. Equally counter-intuitive was the tremendous enthusiasm for the seemingly pedestrian impulsive force (bucket) example or the multiple tank flow system. The latter generated by far the greatest response and involvement; achieving steady state in the three tank system proved to be quite difficult, which students seemed to find both frustrating and engaging. It should also be mentioned that several groups discovered that there was more than one possible configuration that would bring the system to steady state, which they responded to with tremendous surprise. A final surprise was the students interest in the die – there was significant interest in the trajectory of the die after impact with the table. Even though the instructors made no mention of the die, other than as a weight on the darts, many students were fascinated by it.

Some of the hypotheses for these results were: timing and relevance to course material, unexpected results, analytical comfort with the result, tactile quality of the activity, size of the experimental device, and possibility for something going wrong. However, no hypothesis alone describes the commonality of the most engaging activities and there was no clear gender correlated preference. Having a predictor of student engagement would be of particular utility in designing activities in the future but no single explanation was apparent.

Each activity was chosen for its potential for engagement but the strong differential response was a surprise. The authors reviewed photos taken during the sessions, concept
analysis sheets collected from students after each element of a session, and their own recollections of student’s responses. Positive responses were not apparently gender dependent, nor were they dependent on the timing within or among sessions. As a result of this process, it was found that a common factor among the most engaging activities was surprising complexity arising from a seemingly simple system. The multi-tank system is a good example but the die is possibly the best as it is a trivially simple object, a cube. For these systems, students demonstrated surprise at the results and, even if the results were not counter-intuitive, the results were surprising and engaging enough to encourage them to explore independently.

Another discovery during this process was that the author’s interest in an activity and time spent exploring it correlated well with student’s response. The most enjoyable activity for the professors was often, but not always, the most enjoyable for the students. This could mean that, when presenting their “pet” projects, the presenter’s enthusiasm became apparent. While this is possible, the authors made equal investments of time on less than successful projects and had chosen each one as an illustrative activity. It is possible that the instructor’s verbal and/or non-verbal cues indicated their interest and enthusiasm for the activity. Care was taken to remain enthusiastic about each activity, so any cues from the instructor as to their opinion of the merit of the activity would be subconscious. The final possible reason for the correlation of student and instructor engagement is that students and faculty are similar in their engagement response. Towards this end, the authors have planned an additional study to explore instructor and student engagement.

Conclusions
Designing hands-on activities that are engaging is, without quantitative indicators to predict engagement, more of an art than a science. Based on the experiences reviewed here and elsewhere [4], it is best to design examples with elements that are not initially obvious, rather than simple, direct experiments. In the processes of exploring the instructor’s desired physical concept, it is hoped that the student will see additional possible explorations and undertake those as well. This will give students a chance to explore the activity on their own, making it an engaging personal experience that will positively impact their learning [1].

As discussed above, a good predictor of student engagement level was instructor engagement level. It may prove useful to an instructor to spend time with a proposed activity and critically evaluate their own engagement, specifically their interest in exploration of the activity. When selecting a few activities from a larger list, an instructor might perform each activity themselves. While doing so, a record of both the time spent with various activities as well as number of self-directed diversions could be used in selecting the final activities. The primary consideration in designing an engaging hands-on activity might be “Instructor, enthuse thyself!”

Bibliography


**Biographical Information**

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