The Legacy Project: A Tool for Improving Core Skills

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In upper level courses, student backgrounds in central skill areas such as recall of calculus or the ability to use packaged mathematics software can vary widely from student to student. These differences arise from the fact that, despite a fairly uniform exposure to these topics, students are not automatons and they each retain different skills and content from every one of their previous experiences. Additional difficulties in upper level courses are also encountered relating to the different learning styles that are present in the student body. In any given class there will be a number of students who are primarily auditory learners as well as visual learners just as there will be students who are process oriented and students who are concept oriented. To address this varied set of student needs without detracting from available class time, a novel approach, termed a legacy project, was initiated in a 300-level Fluid Mechanics course. The objective of this project is to provide students with a variety of resources for improving their core skills as well as materials presenting alternate approaches to course topics in areas deemed essential to a given course. This paper will discuss the concept and its first contributions; later work will evaluate its use and effectiveness.

The legacy project is a communal learning exercise where current students in a class become teachers and mentors to future students. In this type of project, students in a class develop guides or support documents on selected topics for future generations of students to utilize in their education. By keeping the focus on helping future students, the current students step out of the learner role and into the teacher role so as to present their topic in a clear and measured manner. Over time, a library of resources is generated containing numerous entries for each topic. This duplication of resources allows for different methods and learning styles to be addressed in a course. In this way, students in future sections of the class can sift through the material with a greater possibility of finding a resource that helps them connect with the material in a personal way.

In the Fluid Mechanics class for which this project was developed, students generated resources for topics ranging from double integration using the method of strips for the study of forces on submerged surfaces to using Maple to generate vector plots for flow visualization. “How to Handle …” guides for the control volume formulation of the mass, momentum and energy equations were also strongly encouraged. The projects focused on content where the instructor was reluctant to use large amounts of class time to “level the playing field”, but where a non-trivial number the students demonstrated a need. Interested students were informed of the objectives for the project and provided with a rubric for project generation that focused on accuracy, insight and clear communication.

Borrowing from the shotgun approach used in genomics, projects were open to all students, however only the best submissions are expected to survive for more than a few cycles/iterations. Students from each of the two sections and from all ability levels were
encouraged to submit entries for extra-credit. The assignment of topics to students was not exclusive and duplication was not only accepted, but also encouraged. As a result, struggling students used this exercise to coalesce their understanding of a difficult subject and advanced students used the assignment as an opportunity to give back to the community. As an additional incentive for the highest functioning students, submission of an entry was required as part of an agreement for exemption from the comprehensive final exam.

From a class of 79 students, 20 students chose to submit entries for the legacy project during its first iteration. Of these 20, six were from students whose overall grades were high enough to warrant an exemption from the comprehensive final exam. The topics for which students chose to develop materials ranged from basic tutorials in the use of Excel to flow charts outlining the solution procedure and nuances of the control volume formulation of the momentum equation. The majority of the projects, however, centered around projects that connected directly with some of the most difficult core concepts of the course, most notably the control volume formulations of the momentum equation and the energy equation.

In future terms, students will have access to all of the previous contributions to the project and the persistence of any given student’s contribution will be determined by the maintenance of positive reviews from the future students. The review forms that will be used focus on both the need for the resource as well as the educational quality and usefulness of each submission. With each iteration of the project it is expected that the least useful resources will be discarded because of low rankings and that the best projects will both fill in gaps in the student’s backgrounds and serve as essential resources to improve understanding of the central tenets of the class. The review of student projects also serves to foster critical thinking about the topics and the resources at their disposal. An additional benefit of the review process is that it allows for additional classroom issues to be identified and added to the legacy project’s topic list from semester to semester.

To assess student projects a rubric was developed and published for the students to use when planning their projects (Figure 1). The four focus areas (Accuracy, Communication, Organization, & Scope) were chosen to promote mentorship and to develop the student presenters as educators. For example, in the Communication area emphasis is laid on the use of visual cues and commentary to highlight the nuances of the topic for future students. In the Organization area, students are encouraged to supplement the structure of their clear presentation with graphical elements to obtain a higher grade. For the extra-credit project, a student’s presentation was worth a maximum of 16 points (four for each area): this valuation placed the extra-credit project at 2% of the overall grade for the term.

The implementation of the objectives stated in the rubric varied widely from student to student. Some student presentations were exceptionally linear while others effectively used comments to achieve a balance between explaining the big picture and providing a detailed example. Figure 2 is a single slide from a student PowerPoint resource on the control volume formulation of the conservation of energy. In this resource the student is endeavoring to address the apparent complexity of the relationship that arises in the energy equation because of its many components. The conversational aside that the student includes in the slide is an encouraged approach since the goal here is to have the student adopt the role of tutor to future (unseen) students. Figure 3 is a second slide from later in the same student PowerPoint presentation. In
this slide the student uses “pop-outs” to breakdown the individual elements of the energy equation and to provide moral support for the future students. The remainder of this resource serves as a step-by-step treatment for the components of the energy equation.

![Rubric for Assessment of Student Resources](image)

**Figure 1: Rubric for Assessment of Student Resources**

<table>
<thead>
<tr>
<th></th>
<th>(1) Basic</th>
<th>(2) Novice</th>
<th>(3) Proficient</th>
<th>(4) Distinguished</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>Solution contains conceptual errors</td>
<td>Solution contains simple math/calculator errors</td>
<td>Solution is presented with only simple errors</td>
<td>Solution is presented without error</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>Areas of difficulty are not identified. Formulas and calculations are only tools used to communicate knowledge</td>
<td>Key concepts are identified and isolated.</td>
<td>Areas of difficulty are highlighted using diagrams and written “asides” to add meaning</td>
<td>3+ Solution strategies are discussed</td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>Presentation of material lacks a sequence of information, haphazard presentation.</td>
<td>Presentation is difficult to follow. Logical sequence is interrupted or presented in a disjointed manner.</td>
<td>Information is presented in a logical sequence which the audience can follow. Solution is clearly presented.</td>
<td>3+ Graphical methods are used to present material</td>
</tr>
<tr>
<td><strong>Project Scope</strong></td>
<td>Project has a very narrow scope; focuses only on one specific problem</td>
<td>Project has a narrow scope; focuses only on one class of problems</td>
<td>Project addresses one of the core topics for the course</td>
<td>3+ Illustrates the concepts with a specific problem or example</td>
</tr>
</tbody>
</table>

**Energy Equation**

\[
\dot{Q} - \dot{W}_S = (\rho_2 \overline{V}_2 A_2)(u_2 + \frac{\alpha_2 \overline{V}_2^2}{2} + g_2 + \frac{P_2}{\rho_2}) - (\rho_1 \overline{V}_1 A_1)(u_1 + \frac{\alpha_1 \overline{V}_1^2}{2} + g_1 + \frac{P_1}{\rho_1})
\]

This is the Energy Equation. Looks pretty bad doesn’t it? This presentation will go over what each part of it is and show how to use it in 5 simple steps.

**Figure 2: Selection from a Student PowerPoint Guide to the Energy Equation**

*Proceedings of the Spring 2007 American Society for Engineering Education North Central Section Conference at West Virginia Institute of Technology (WVUTech), March 30-31 2007*
Figure 3: Selection from a Student PowerPoint Guide to the Energy Equation

Figure 4: Excerpt from Student Flow Chart for Solving the Linear Momentum Equation

"Proceedings of the Spring 2007 American Society for Engineering Education North Central Section Conference at West Virginia Institute of Technology (WVUTech), March 30-31 2007"
Figure 4 is an excerpt from a student-generated flow chart addressing the process of solving the momentum equation. In this resource the student has included a visual element by highlighting all of his or her own comments in blue (overwritten with dashed lines in the figure). In generating this resource the student reflected on his or her own experience while learning the process and re-expressed this in a compact form that other students could quickly access. While this resource only focuses on the mechanics of the process, it is useful for those students who need to focus on the techniques involved in integration and the dot-product before they can address the broader issue of force balance.

Figure 5 is a large excerpt from a student discourse on developing vector plots using the Maple software package. Students at Kettering University have an early exposure to Maple in their Calculus classes; unfortunately, it was found during the course of an exercise that many of the students either did not have the recall needed to utilize the software in class. It was also found that some students did not have sufficient exposure to any mathematics software package for it to be successfully utilized in their 300-level Fluid Mechanics class. To remedy this for

Doing Vector Plots in Maple

One of the easiest and fastest ways to plot a vector field is by using Maple. In the example below, the velocity field \( \mathbf{V} = (0.5 + 0.8x, 1.5 - 0.8y) \) is plotted in the domain between \( x = -2 \) and \( x = 2 \) and \( y = 0 \) to \( y = 5 \).

1. The first step is to load the commands for doing vector field plots, “fieldplot” and “fieldplot3d”. To do this, you simply type: with(plots);

```
> with(plots);
Warning, the name plots has been redefined
```

   Failing to use this command
   will make it impossible to
   use the field plots

2. Next you must define your vector field. Using the field given above, we have:

```
> V := (0.5 + 0.8*x, 1.5 - 0.8*y);
```

   Make sure you use
   `:=` not just `=`

3. With the field defined, we can now plot it. The command for two dimensional plots is “fieldplot”. The command has several arguments as shown below.

```
fieldplot(V, x=-2..2, y=0..5, options)
```

The options affect how the plot looks. For us the important ones are grid, thickness, and arrows.

- The grid being referred to is the grid of vectors being plotted. For example, to plot 25 vectors:

```
grid=[5,5]
```

   where 5,5 is the dimensions of the vector grid.

- Thickness affects the line weight. Simply experiment until it looks correct. For example:

```
thickness=2
```

- The arrows option lets us choose the arrow style. The values are Line, Thin, Thick, and Slim. For example:

```
arrow=thin
```

Figure 5: Selection from Student Discourse on Using Maple to Generate Vector Plots
future classes without detracting from class time or adding several hours of preparation time to either re-introduce Maple or to introduce another product such as MATLAB or Mathcad, it was decided that the issue would become a topic area for the legacy projects. In this example of the student projects on this topic, the presenter assumed that the future students would be able to recall the basics of Maple and focused his attention on extending their knowledge base to generate vector plots and control the plot display. To accomplish this goal the student presenter used an academic example as a motivating factor and included screen shots of the syntax and output to guide their progress. The student also utilized color-coded “pop-outs” to elaborate on the intricacies of the Maple programming language. The student also demonstrated significant initiative by expanding the project to include two practice problems along with their final solutions for future students to use as a resource. With this type of classroom problem, the advantage of a legacy approach is that the posted material can easily be expanded upon if it is found that a large number of the future students do not have a strong enough recall of the basics to use this resource.

At the end of the term, those student projects that have met the requirements of the rubric are posted for future classes to use and review. In this first implementation of the process, student contributions were consistently of high quality, however, many of the students exclusively used flow charts to graphically illustrate the methods and concepts. To adjust for this in future classes and promote different approaches, the phrasing of the topic list and rubric will be used to steer or re-direct the submissions. Future papers will detail the evaluation process and report on the effect that these resources have on student skill sets. Finally, although many students relate to this approach by drawing parallels to the Wikipedia project that is currently available on the internet, it should be noted that the reviews and the use of the rubric in the legacy project permits the evolution of better and better resources over time and that none of the entries are considered definitive.