AC 2011-1798: STUDENT DESIGNED DESKTOP MODULES IN A THERMODYNAMICS COURSE

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Student Designed Desktop Modules in a Thermodynamics Course

Abstract

There has been much recent work on incorporating hands-on modules inside the chemical engineering classroom. Arce emphasizes the use of student-designed and built modules (which he calls experimental prototypes) in fluid dynamics. Likewise, Minerick has used desktop modules that are faculty designed but are literally small enough to fit on the desktop. Finally, Van Wie has shown the utility of an all-in-one hands-on device specifically designed by faculty for use in fluid dynamics. It is the intention of the author to try and synthesize the best features of each approach. In particular, the author would like to have student-designed and built modules that fit on a desk or table-top, which can be used to explore multiple concepts. As a first step in this approach, students in a thermodynamics course at Tennessee Technological University were assigned the task to design and build a desktop module. The purpose of this step was to identify those designs that might best lend themselves to repeated use and/or address multiple concepts. Once built, the students demonstrated their device to their classmates and were assessed by upperclassman who had already taken the course for efficacy at concept demonstration. In a follow-on year, the next groups of students were assigned the task to modify the existing desktop modules in order to better expose the most salient thermodynamic concepts of the particular desktop module. This paper provides an update on the approach to this point.

Introduction

Hands-on learning is an engagement strategy that purports many educational benefits, most notably an improved concept learning.[1] This experiential learning approach is increasingly popular in engineering disciplines across the United States. In fact, a simple search of the term "hands-on" of the ASEE Conference Proceedings archive from 1996 – 2010 identified 213 papers with that search term in the *title* alone. These papers are from many disciplines within engineering and cover all levels of students, such as Freshman projects where students are involved in the design process[2] or in working with modules[3], to multidisciplinary design projects[4] and many implementations in between.

Within the field of chemical engineering, Arce (among other faculty) recently has had students design and build modules (he called them experimental prototypes) to demonstrate chemical engineering concepts, such as flow meters, though they varied greatly in size.[5] Minerick, on the other hand, has used faculty-designed and built modules that do fit on a desktop (called a Desktop Module or DEMo) that allow students to explore heat transfer concepts.[6] Finally, Van Wie and coworkers have designed and built desktop learning modules (or DLMs) that allow for the exploration of many concepts efficiently through the use of modular cartridges.[7]

However, imagine a learning environment where students are not seated at a desk or table in neat rows/columns, but are in a work area that contains a seat, a place for a computer/notebook/data acquisition device and a small, modular piece of equipment that the student has helped design and build, which can allow for multiple concept exploration during the semester. Such an approach would integrate the three ideas of Arce (student designed and built), Minerick (desktop) and Van Wie (multi-conceptual).

As a first step towards integration, the author had students in his thermodynamics course at Tennessee Technological University (TTU) tasked with the challenge of designing and building a device that demonstrates a single thermodynamics concept, yet can fit on a desktop. A main purpose of this step was to help identify which devices would lend itself to repeated student use. Once the devices were built, the students had to demonstrate the devices to their classmates and were also assessed by upper-classmen who had already taken the course the previous semester for efficacy of concept demonstration. In a follow-on year, the next group of students had to take the existing modules and refine them such that they improved the demonstrations of the concept and adhered to the size constraints of the project. This work is an update on this process.

Student Design Desktop Modules – The Process Plan

In an effort to best describe the overall goal of the project, it is illustrative to sketch out a long-term implementation plan. As such, a seven-year plan is provided, which allows ample time for feedback and refinement of the ideas. While seven years might seem like a long time, the process has refinement/feedback steps incorporated directly. The outline of this process plan is provided below.

Year 1: Students design and build a desktop module to demonstrate a single thermodynamics concept.

Year 2: Students take existing student-designed modules from the previous year and refine them to better demonstrate concepts and match desktop requirement.

Year 3: A subset of the previous year's projects are designed and built by the students, this time focusing on synthesis and manufacture efficiency.

Year 4: The previous year's projects are analyzed by students in order to design a process to allow them the ability to demonstrate multiple concepts. An attempt at building the projects to incorporate multiple concepts are made.

Year 5: Multi-concept modules are designed and built by the students.

Year 6: A subset, if applicable, of the previous year's projects are designed and built by the students, focusing on manufacture efficiency.

Year 7: Launch curriculum where students design (conceptually) and build multiple modules in a semester and use these modules on a regular basis to explore multiple thermodynamics concepts inside the classroom.

Overview of Year 1

It must be stated that Year 1 is not truly the first year the author has used some form of project design in his class, but it is the first year that the thought of integrating the projects inside the classroom on a desktop has occurred. The students who were involved in the Year 1 course were first semester, junior-level students (33 ChE and 3 CEE) at TTU. There were nine teams of students and each team contained four members. The teams were solely decided by the instructor based on an analysis of the students' college transcripts and the instructor's knowledge of the students from previous interactions. The teams had roughly equivalent science/math/engineering GPAs. The team leaders were chosen solely by the instructor based on, in his opinion, which students could benefit from a team leadership experience.

The students were informed on the first day of the course about the desktop learning module project. It was to comprise 10% of their overall course grade. Student teams were given a maximum budget of $400 and had to have all potential expenditures approved by the instructor. The instructor would make all purchases after approval (in order to save on tax).

Students were also informed that there would be a presentation/demonstration at the end of the semester of their module, a write-up/procedure that other students would follow about their module (with a 100% correct report attached by the team) and, finally, a detailed project report. At the end of the semester, the student groups would archive all of this electronically and send it to the instructor as well (for the teams to use in the follow-on years). Detailed information was provided to the students on the syllabus as to why this activity was occurring. This has been repeated below:

> While there is an increasing movement towards "hands-on" learning, especially in engineering, such an approach is mainly focused on modified laboratory experiences and/or out-of-classroom experiences. However, most of the contact hours in a curriculum occur inside the classroom and, thus, this creates a challenge to implementing a hands-on strategy. To this end, we look to develop desktop prototypes that students will use inside the classroom on a regular basis to promote the conceptual understanding of thermodynamics concepts. Since these desktop prototypes do not exist, this plan will focus on student design/development/construction/testing/evaluation of such prototypes. It must be emphasized that this plan is different than having students develop/design large

equipment for use in a laboratory setting. The focus in this work is on desktop devices that can be used throughout the semester inside the classroom to explore multiple thermodynamic concepts. It is anticipated that once these devices are successfully created, subsequent classes (the following years) will utilize them.

The nine projects, which were selected by the students after consultation with the instructor, were as follows:

- Hydro-electric Power Generation
- Static Calorimeter
- Flow Calorimeter
- Steam Engine
- Stirling Engine (alpha type)
- Stirling Engine (gamma type)
- Real vs Ideal Gases
- Work-energy Theorem
- Tesla Turbine

Some representative pictures of the completed projects from Year 1 are provided in Figure 1

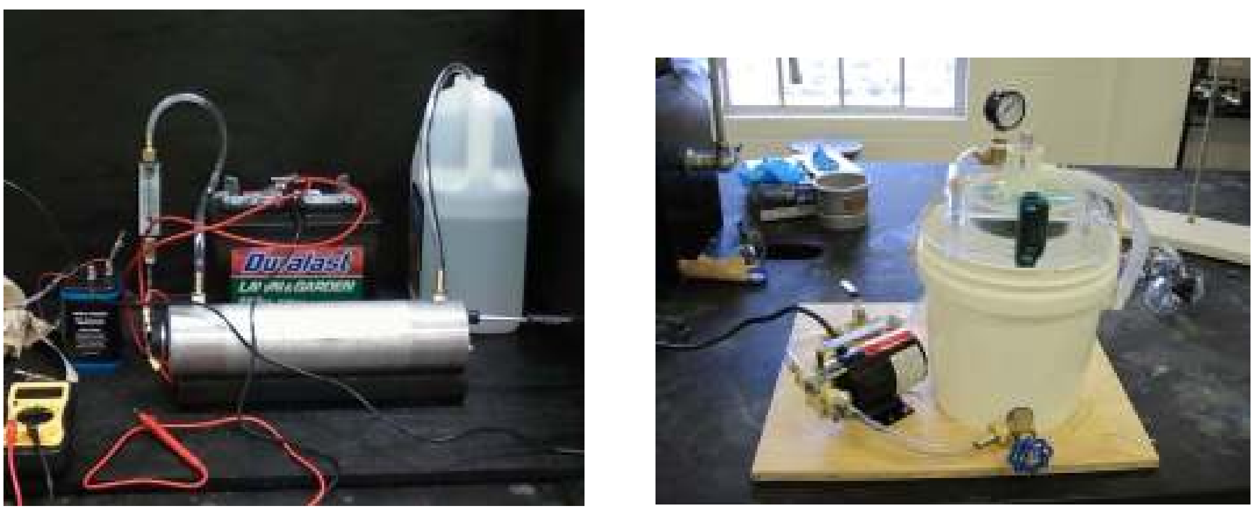

Figure 1: Flow calorimeter (left panel) and Tesla turbine, water-powered (right panel)

The team leaders (and teams) met with the instructor as often as their team requested it to obtain feedback on any project questions. The teams were encouraged to identify the parts they needed so the instructor could purchase them in time for their use. The instructor regularly reviewed their plans to build their equipment. With regards to building the devices, the department's technician was available to provide both tools/equipment as well as fabrication expertise and support, as warranted.

As described above, there were three groups assessing each project: (1) same-class student peers, (2) senior-class students and (3) faculty. Groups 1 and 3 used the same assessment sheet which was given to the students well in advance of the end of the semester. This is provided in Appendix A and was used to assess the project demonstration alone. The senior-class students were given a different assessment sheet that focused on both the desktop nature of the module as well as the utility as a learning aid from their unique perspective and was also based on the project demonstration alone. The instructor, on the other hand, assessed the written portions of the project based on a standard assessment rubric given to the students for project reports.

Once the presentations and demonstrations were completed (each group was given about 20 minutes), the instructor compiled all of the assessment sheets. After grading of the project reports, a final, detailed feedback form was provided to each team during finals week which summarized the assessment of their project. It also included the verbatim written assessments provided by the student peers and faculty.

While the faculty and peer assessments (Groups 1 and 3) provided an evaluation on whether the project demonstration met the objectives, the senior-class student assessment (Group 2) was different. This sheet is provided in Appendix B and had questions which focused on:

- Whether those senior students would have learned the concept better if they had access to this DEMO when taking the course the previous year
- Whether the device could be modified for future years
- Whether it could be used for multiple concepts
- How any measured values from the desktop module were used in various formulas for that team's specific concept.

The assessment provided by the cohort of senior students allowed the instructor some additional insights on which projects would be best used to modify for the Year 2 phase. Note as well that the students were also informed of an opportunity to present their work as part of an ASEE SE Section meeting, which has a competition devoted to the work of undergraduate student teams. The Group 2 assessments were instrumental in identifying the project to nominate for that meeting.

Instructor Insights From Year 1 Projects

The hands-on nature of the projects were very rewarding from a student standpoint since, for many students, this was their first real attempt to build something mechanical. Leaks were the norm as students struggled with design questions, other courses they were taking, building something from "scratch", making the desktop module small enough to fit on the desktop, working/interacting with a technician, etc. While several projects did adhere to the desktop requirements and demonstrated the concept in a reasonable manner, others did not. This feedback was important for the instructor as it provided insights as to those projects that would be available for students to modify in Year 2.

Overview of Year 2

The Year 2 cohort had 44 students (41 CHE; 3 CEE), which were divided into eleven teams. The student team leaders were shown all of the available projects (from Year 1 and few from a previous year since the number of teams was greater in Year 2 than Year 1) and, after consulting with their teammates, identified the project they would modify. The eleven projects chosen were as follows:

- Hydro-electric Power Generation
- Static Calorimeter
- Flow Calorimeter
- Stirling Engine (gamma type)
- Real vs Ideal Gases
- Work-energy Theorem
- Tesla Turbine
- *Sensible heat evaluation*
- *Dehumidifier*
- *Refrigerator*
- *Joule's Experiment*

The four projects in italics were from a previous year. Students were provided the same detailed information in the syllabus about the desktop module as in Year 1, but were told that last year's students already completed that. The Year 2 students were told that they were to modify those projects to fix short-comings indicated in the assessments from Year 1. Relevant project reports were handed over (with grades redacted), which gave the new student teams a place to start. They were also given the name of the team leader from the previous year(s) to use as a reference/resource.

In an effort to help mitigate students back-loading the work on the project to the end of the semester, teams were required to hand in a weekly memo, which updated the instructor on the progress on their project. The instructor read the memo, responded to it by the next class period and followed up on any issues that needed to be decided. In addition to student-initiated meetings during the semester with the instructor to answer questions, the instructor met with each team (and their project) during the mid-semester to evaluate progress on the desktop module modification. While time consuming, this meeting was beneficial to both parties since there were issues about equipment, which are sometimes not explained well in conversation or via a memo.

With regards to assessment, the projects were assessed by only their peers and the instructor in Year 2. The presentations were evaluated using the form from Appendix A, but with a new question added:

- The team discussed how they have modified the previous year's design and why they made the modification they did

Additionally, as in Year 1, the students were required to submit a project report as well as a write-up for 10 – 15 minute activity around their module (with a 100% correct report). The rubric to assess these parts of the project was provided to the student teams during the semester.

It is informative to describe the types of modifications made to some of the projects by the students from Year 1 to Year 2 to give a flavor for the types of insights and changes that were associated with going from Year 1 to Year 2. Three of these are reported below.

Hydro-electric Power Generation – This project pumps water from a reservoir to a height above a water wheel. The water then falls by gravity on the water wheel, which turns a shaft on a generator and lights a light bulb. The students decided that their goal was to calculate the efficiency of process (work output per work input). During Year 1, the student team specified a pump they determined would be just powerful enough to overcome the required height above the water wheel. However, upon implementation the pump was not powerful enough and the student team resorted to a purely gravity feed process. The Year 2 team sized the pump with excess power and made a more self-contained project, with a simple tachometer to determine power output in an efficient way. Such an approach better adhered to the desktop goal.

Static Calorimeter – This project involved having water (as a reservoir) in a metallic container surrounded by a flexible tote bag. The water was heated using a fish-tank heater (attached to a battery) with a port for the sample chamber. The project was a calorimeter to determine the heat capacity of a sample, which demonstrates the 1st Law of Thermodynamics using sensible heat changes. The Year 2 team changed the metallic container to glass and used rigid Styrofoam instead of the flexible tote to better insulate the reservoir. They also calculated the heat loss rate for the system with no sample in order to better quantify the error associated with a perfectly insulated assumption. This was an important step and insight for this team as it is normal for students to regularly cite various "experimental errors" in projects/labs with no attempts to quantify those errors. That this group attempted this (successfully) was well lauded by the instructor and was an effective teachable moment for the other teams.

Dehumidifer – This project involved taking air from a room, lowering the temperature of the air (using a cooling water stream) below its dew point to draw water out of that air and return the air to the room. The project tried to predict the relative humidity of the air leaving the dehumidifier when compared to that measured by a hygrometer. The Year 1 project team had little experience working with their hands, which proved a challenge and a good learning experience. While the project did remove some water from the air, the cooling water hook-ups defeated the intended "desktop" nature of the project. Additionally, the project leaked at various connection points. The Year 2 students initially tried to use this design as well, but quickly scraped that approach and developed a new strategy. These students identified the need to heat the less humid air back to room temperature (which was not done by the Year 1 students) as well as focus on making the desktop module fit on a desktop. They arrived at a clever design that used a PVC pipe partitioned in two down the middle that used Peltier devices and sinks to both cool the air (on one side) and heat the air (on the other side). The device was vertical, which allowed gravity to drain the water to the bottom of the device (with a drain plug). A visual comparison between the dehumidifier projects in both years are provided in Figure 2.

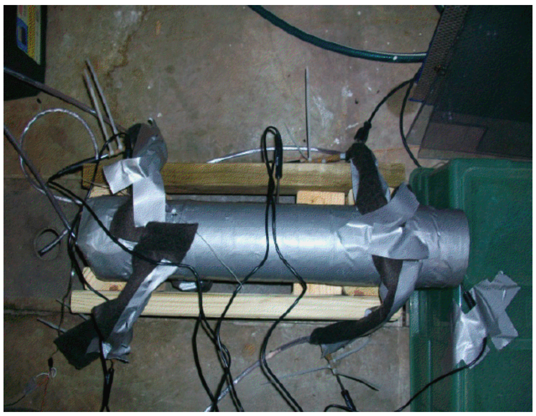

Figure 2: Dehumidifier, Year 1 (left panel) and Year 2 (right panel)

Instructor Insights From Year 2 Projects

The use of weekly memos was effective at getting teams to make regular progress throughout the semester as opposed Year 1. Additionally, the teams were more sensitive about the desktop nature of the modules in Year 2. It also revealed that some projects will not move forward to the next stage of evaluation, like the Stirling Engine projects that require precision design and manufacture to run effectively. Such objectives are beyond the scope of the plan for junior chemical engineering students.

Conclusions and Future Work

The goal of the project, overall, is to develop a protocol where students efficiently design and build a multi-concept desktop module in a thermodynamics course, which can be used as a learning aid throughout the semester. This work reports on the first two years of a strategy to synthesize previously published work on using hands-on modules within chemical engineering courses. The first attempt to implement Year 3 will focus on a smaller subset of projects as well as attempts to miniaturize the various successful project ideas.

References

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Appendix A

CHE 3010 DEMO Project Assessment (09F)

FACULTY/STUDENTS

TOPIC OF THE PRESENTATION ______________________________

(Circle the proper number)

	Agree	*Neutral*	*Disagree*
The team was quite clear in the particular thermo concept they were demonstrating	3	2	1
The team discussed the "desktop nature" of the project, which was a stated goal	3	2	1
The team prepared a useful schematic of their device	3	2	1
The team discussed predictions they were making associated with their device	3	2	1
The team discussed and properly estimated errors associated with the output of their device	3	2	1
The team discussed obstacles they faced and how they overcame those obstacles	3	2	1
The team presented a detailed budget of expenditures associated with this project	3	2	1
At the conclusion of this presentation, it was clear that each group member participated in a meaningful way	3	2	1
The team had a good understanding of the concept they were demonstrating	3	2	1
The presentation/poster was prepared in a professional manner (proper font size, useful graphics, slides not cluttered, etc.)	3	2	1
The team discussed relevant lessons learned associated with completing this project	3	2	1

GENERAL FEEDBACK:

Two (or more) positive comments on this presentation and demonstration:

1.

2.

One (or more) area of *constructive* criticism:

1.

Appendix B

CHE 3010 DEMO Project Assessment (09F)

SENIOR STUDENTS

TOPIC OF THE PRESENTATION ______________________________

(Circle the proper number)

	Agree	*Neutral*	*Disagree*
The team was quite clear in the particular thermo concept they were demonstrating	3	2	1
The team discussed the "desktop nature" of the project, which was a stated goal	3	2	1
I would have learned the concept better if I had access to this DEMO when I took ChE 3010	3	2	1
I could see where such a device might be modified (or used, as is) on the desktop/in the classroom	3	2	1
The device can potentially be used to demonstrate multiple concepts	3	2	1
It was clear to me where measurements (T, P, etc.) were used within the formulas	3	2	1

GENERAL FEEDBACK:

The two best aspects of this DEMO project were:

1.

2.

One area of improvement I would suggest before utilizing this project as a DEMO would be:

1.