Application Details

Manage Application: Innovation and Excellence in Laboratory Instruction Award - 2018

Award Cycle:	2018
Internal Submission Deadline:	Friday, February 2, 2018

Application Title:	Breedveld
Application ID:	002169
Nominator's First Name:	David
Nominator's Last Name:	Sholl
Nominator's Title:	Professor and Chair of the School of Chemical & Biomolecular Engineering
Nominator's Primary Organization:	College of Engineering - School of Chemical & Biomolecular Engineering at Georgia Tech
Nominator's Email Address:	david.sholl@chbe.gatech.edu
Nominator's Phone Number:	404 894 2822
Nominee's First Name:	Victor
Nominee's Last Name:	Breedveld
Nominee's Title:	Associate Professor and Associate Chair of Undergraduate Studies in ChBE
Primary Organization(s):	ChBE - Chemical and Biomolecular Engineering
Nominee's Email Address:	victor.breedveld@chbe.gatech.edu
Co-Applicant(s):	--

2018 CTL Innovation and Excellence in Laboratory Instruction Award

Nomination packet for Dr. Victor Breedveld (ChBE)

Experiential Learning in Transport Phenomena Lecture Courses

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Executive Summary

The innovative contribution of Dr. Victor Breedveld is that he has added experiential learning components to two junior-level core ChBE courses (Transport Phenomena I + II) in the form of take-home “bucket experiments” and by bringing experiments into the classroom via live Skype connection to the Unit Operations instructional lab. Students gather and analyze experimental data themselves, either in a guided classroom setting from an existing laboratory set-up, or -with limited guidance- in small groups at home, where they have to design and construct their own experimental apparatus. The objective was to expand major-related hands-on experiences from the senior year into the junior year within the confines of the current curriculum. The innovation was positively reviewed by students; preliminary analysis of exam performance has also shown significant learning benefits.

Background and Objectives

Within the ChBE undergraduate curriculum, major-related laboratory experiences have mostly been delayed until senior-level courses (CHBE 4200/4210 Unit Operations Lab and CHBE 4412 Process Control

Lab), which are generally taken during the final two semesters before graduation. There has been a desire among ChBE faculty to offer students more hands-on experiential learning opportunities in earlier stages of their education. Such experiences are not only beneficial for students with more visual and tactile learning styles, they can also help to bridge the perceived disconnect between core lecture courses and industrial practice, a comment that is often heard from students who participate in co-op and internship programs.

Dr. Breedveld has added experiential learning to traditional junior-level lecture courses, CHBE 3200 and CHBE 3210, in two innovative ways: (1) live experimental demos in the classroom, and (2) take-home "bucket experiments". These innovations provide ChBE undergraduates with new experiences that help them master key concepts of chemical engineering and expose them to the challenges of designing experiments, analyzing data and reflecting on observations, all within regular lecture-based courses. The objective was to create new experiences that satisfied the following boundary conditions: *(a)* do not add to the already high workload of these courses by integrating new activities with existing homework assignments or replacing a regular homework assignment, *(b)* provide open-ended problems that require the students to design their own experiments and reflect on the consequences of their design choices, *(c)* minimize the potential for and temptation of honor code violations by creating sufficient flexibility and uncertainty in the experimental tasks and results to ensure long-time viability, *(d)* create easily transferable material that can be taught by all instructors for these core courses, which are both taught three times per year.

Skype Classroom Experiments

Since Spring 2015, Dr. Breedveld has brought experiments into the ChBE 3210 classroom: one class period each semester is devoted to carrying out live experiments with heat exchangers, a key concept of the course. Because of the size of the equipment and the required connection to hot and cold water supply, it is impossible to bring equipment into the classroom. However, a Skype connection to the ChBE Unit Operations Lab with video-feed of the set-up, including clear view of all valve positions, and screen sharing of the output signals from four thermocouple temperature probes, provides students with a front-row seat of the ongoing experiment. Through the Skype connection, Dr. Breedveld and the class can provide instructions to an assistant in the UO Lab to change physical settings on the equipment, and then observe the changes in temperature responses via the live connection.

Students in the class decide when signals stabilize and read off the corresponding temperatures themselves. The first couple of experimental settings are always scripted by Dr. Breedveld to ensure that key phenomena are included in the data set, but then the class directs the final experiments that are performed. The data that is thus collected during the class period, incl. all the artefacts and errors one would expect to be present in real experiments, must then be analyzed as part of a homework assignment. Rather than using textbook numbers to analyze heat exchanger performance, the students use their own real-life data, which forces them to think about explanations that go well beyond standard textbook details. For example, we have found that the building water temperature, which fluctuates during the year, can affect the data. In another case, the analysis showed that one of the sensors had to be broken. The homework assignment is a combination of quantitative analysis and reflective qualitative questions and is assessed like any other homework: a TA prepares a solution key together with Dr.

Breedveld, which is then posted online for the class, and the same TA then grades all submitted assignments.

Dr. Breedveld has refined the heat-exchanger demo over the course of four semesters (Spring 2015, Summer 2016, Spring 2017 and Summer 2017), and the protocols are now ready for adoption by other faculty. Other experiments in the Unit Operations Lab have been identified that can be used to expand this idea to other courses (e.g., fluidized bed in CHBE 3200).

Take-home Experiments

In Spring 2016, Dr. Breedveld submitted a Tech Fee proposal to purchase the equipment for take-home experiments in both CHBE 3200 and CHBE 3210, which each are taken by about 250 ChBE students annually. The objective was to develop hands-on experiences for all ChBE students in a way that was scalable to a lecture course with 100+ students and easily transferable to any instructor, while still avoiding the prescriptive "fill-in-the-blanks" nature of basic science labs. The $21,000.- proposal was awarded and in Fall 2016 (CHBE 3200, 114 students) and Spring 2017 (CHBE 3210, 101 students), bucket experiments were implemented. Both experiments have been refined and reused in subsequent semesters: Spring 2017 for CHBE 3200 (Dr. Hang Lu, 105 students) and Summer 2017 for CHBE 3210 (Dr. Breedveld, 45 students). Starting in Spring 2018, the "bucket experiments" are being used as part of the standard curriculum, independent of instructor. As a result, these innovations will impact all ChBE undergraduates.

Figure 1. Examples of mandatory group pictures supplied by students as part of their reports.

In both of these courses, groups of 3-5 students receive a 5-gallon bucket with unassembled equipment (aquarium pump and tubing for CHBE 3200; mini fan and various cylinders for CHBE 3210) and various measuring tools (stopwatch, ruler, thermometer, tape measure, etc.; see assignment descriptions in

Appendix for details). An assignment with limited instruction on how to exactly perform the tasks is also provided; only minimal instructions are given about assembly of the experimental set-up, in order to promote creative solutions and thoughtful planning (see Appendix). The final deliverable is a brief report, which includes description of experimental plan and procedures, presentation of raw data and analysis (incl. tables and/or graphs), and conclusions. The report must also include an "action picture" of the entire group with equipment to ensure full participation (see below for examples). The intended workload of these "bucket experiments" is 10-12 hours for each student, which is equivalent to about 1.5 homework assignments in these courses.

In addition to the report, which determines the project grades, each group is also required to report key findings (numerical values) in a standardized Excel data summary sheet, so that results from all groups can readily be compared in aggregate graphs that highlight the variation in answers. This information is provided to the entire class as feedback during a class period. Showing the inevitable wide spread in experimental results always surprises the class and is a perfect segue into a discussion about potential errors in approaches taken by various groups, the level of credibility of various outcomes, silly errors and serious misconceptions. Because of the variation in potential outcomes, this discussion never focuses on a "right solution"; instead Dr. Breedveld guides the students through self-assessment of their results. This feedback is intended to elevate students above the "plug and chug" approach that is all too characteristic of many engineering courses.

The Appendix contains the actual project assignments as provided to students for both experiments.

Evaluation

Evaluation of the innovations has happened in several ways: (1) targeted surveys after completion of assignments, (2) post-semester CIOS surveys, (3) performance analysis on related exam questions.

The Skype experiments have not been assessed in great detail, but the same clicker question (Learning Catalytics) was asked in class during the past three offerings. Aggregated data presented in Table 1 clearly indicate that only a minority considered the Skype experiments a waste of time; the vast majority was decidedly positive or neutral. Although quiz and exam questions are always asked on the topic of heat exchangers, there is no clear objective evidence of significant impact on test performance. Anecdotally, based on conversations with students and CIOS survey comments, for a sub-population of students the experiments are extremely helpful for mastering key concepts, in particular those who have more visual and tactile learning styles.

Table 1. Survey results from in-class Learning Catalytics clicker question for Skype heat exchanger demo (aggregate results for Summer 2016, Spring 2017 and Summer 2017)

Question	***Results (144 respondents across 3 semesters)***	
What is your opinion about the live Heat Exchanger Demo in class?	*A. Helpful; you should definitely do this again next semester*	*49.3%*
	B. May be a good idea, but not in current format	*19.4%*
	C. Not useful; not a good use of class time	*8.3%*
	D. Neutral; no strong opinion about this	*19.4%*
	E. Don't know; I wasn't there, or slept through the whole thing	*3.5%*

The bucket experiments have been assessed in greater detail. Table 2 presents the survey results that were collected one week after project report submission in Fall 2016. When Dr. Hang Lu polled her class in Spring 2017, student answers were essentially the same. Notable results are that a vast majority deemed the project a positive experience (81% vs 13%), most students even considered it "fun", and the self-reported time spent on the project matched the design goal remarkably well. It must be noted that the self-reported degree of learning was rather mediocre, with 68% reporting that they only learned a little. However, an objective performance analysis of a final exam question proved that students grossly underestimated the project benefits. On a final exam question about the core content of the bucket experiment (pipe network friction and pump performance), the Fall 2016 class on average scored 81%; in contrast, in Summer 2010, a class scored 57% on essentially the same question, which is a much more typical score for Dr. Breedveld's exams, which are designed with a targeted overall average score of 60-65%. CIOS surveys did included a few negative comments about the project (no specific project-related questions, open comments only), but many positive notes; for class projects in engineering lecture courses this is an unusually positive balance.

Table 2. Survey results from in-class Learning Catalytics clicker questions from Fall 2016 take-home experiment in CHBE 3200

Question	***Results (95 respondents out of 114)***	
1. Was the project fun? (compared to other educational experiences)	*A. Yes*	*66%*
	B. No	*20%*
	C. No opinion	*14%*
2. How many hours did you personally spend on the project?	*A. < 4 hours*	*5%*
	B. 4-8 hours	*20%*
	C. 8-12 hours	*47%*
	D. 12-16 hours	*11%*
	E. > 16 hours	*17%*
3. Did the project enhance your understanding of key concepts about pipe network friction and pumps?	*A. Yes, it helped me greatly*	*21%*
	B. Yes, but not by much	*68%*
	C. No, but I already knew everything	*3%*
	D. No, I still have serious problems with these concepts	*7%*
4. Taking everything into account (weight of grade, time spent, learning benefits) was the project a positive experience?	*A. Yes*	*81%*
	B. No	*13%*
	C. No opinion	*6%*

In CHBE 3210, evidence of improved exam performance was less direct, because no good question was available for direct comparison with a control group that did not perform the bucket experiment. However, in spite of the lack of quantitative comparison, class performance on related exam questions in both Spring 2017 and Summer 2017 strongly suggested that the project helped students master the concepts of convective heat transfer. Table 3 shows direct survey data from Summer 2017 for the CHBE 3210 bucket experiment. Again, the student verdict was remarkably overwhelmingly positive. It is noteworthy that all 40 respondents in Summer 2017 also participated in the Fall 2016 Transport I experiment; the group consisted entirely of students who either were off-campus in Spring 2017 (co-op, internships, etc.) or failed CHBE 3210 in Spring 2017 and retook the class in Summer. Polling data for Spring 2017 (not shown) was decisively less positive than the results in Table 3, and adjustments were made to the assignment to improve student experiences between Spring 2017 and Summer 2017. Although no quantitative data was obtained about workload for the CHBE 3210 experiments, informal discussions with the students confirmed that it was in the targeted range of 10-12 hours.

Table 3. Survey results from in-class Learning Catalytics clicker questions for Summer 2017 take-home experiment in CHBE 3210

Question	***Results (40 responses out of 45)***	
1. Was the project fun? (compared to other educational experiences)	*A. Yes*	*49%*
	B. No	*28%*
	C. No opinion	*23%*
2. Did the project enhance your understanding of key concepts about transient heat transfer and convection?	*A. Yes, it helped me greatly*	*30%*
	B. Yes, but not by much	*68%*
	C. No, but I already knew everything	*0%*
	D. No, I still have serious problems with these concepts	*3%*
3. Taking everything into account (weight of grade, time spent, learning benefits) was the project a positive experience?	*A. Yes*	*89%*
	B. No	*0%*
	C. No opinion	*11%*
4. In comparison with the Transport I project, this project was:	*A. More interesting/useful for learning the material*	*40%*
	B. Similar in terms of learning benefits	*50%*
	C. Less interesting/useful for learning the material	*10%*
	D. N/A; I did not do a bucket experiment for Transport I	*0%*

Conclusions and Next Steps

Dr. Breedveld's innovation has changed the student experience in two core lecture courses without radical curricular changes. The inclusion of experiential, hands-on learning has diversified the experiences so that the courses better serve students with a broad range of learning styles, and stimulate thoughtful design of simple experiments and critical assessment of resulting data. Test results (exams and quizzes) indicate that the students have improved understanding of key concepts after participating in the hands-on learning. Importantly, the students' perception of their own learning is also affected positively.

Starting in Spring 2018, the bucket experiments for CHBE 3200 and CHBE 3210 are part of the standard curriculum for both courses and will be used by all instructors. The positive effects of this innovation have also seeded plans among ChBE faculty for implementation of additional hands-on experiments in core courses. In particular, a Technology Fee proposal has been submitted for a significant design and construction project in CHBE 2100, the introductory chemical engineering course.

Appendix – Project assignment instructions

ChBE 3200: Take-home Experiment
Fall 2016

Instructions

Objectives:

The take-home experiment has three key objectives/deliverables that must be addressed through a combination of experiments and data analysis:

1) **Determination of the pump curve for a basic aquarium pump**
2) **Analysis of relative flow rates in parallel pipes in split flow**
3) **Determination of frictional losses of a contraction/nozzle**

The final product of the project will be a brief report (supported with appendices with raw data and sample calculations) that describes the experiments, data analysis and conclusions for each of these objectives.

Project evaluation:

The project grade will consist of 4 elements:

1) **Equipment care (10%)** – state of equipment upon return; kit should be complete, clean, dry and neatly organized; any equipment issues must be reported upon return, unreported damage will be penalized; self-reported issues will be treated much more leniently, provided that they are not the result of gross negligence.

2) **Quality of experimental data (30%)** – although there is no “right answer” in terms of data, well-planned experiments yield high-quality data enabling meaningful, strong conclusions, while poorly conceived experimental plans do not allow you to perform the analysis that is needed.

3) **Quality of analysis (30%)** – even excellent experimental is useless without thoughtful analysis to extract all available information.
4) **Clarity of report (30%)** – final report should not exceed 10 pages (incl. figures, but excl. supplementary information in appendices like raw data and sample calculations); for each objective, you must describe the experimental method, report results and analyze the data to achieve the 3 project objectives.

The report should be structured in three subsections, each addressing one of the project objectives. This is a technical report, so clarity and effectiveness of your writing are key; no need for a prosaic masterpiece.

Equipment:

The following equipment is made available to you:

- 5-gallon bucket as reservoir
- Aquarium pump that can be mounted to the bottom of the bucket with suction cups
- Permanently attached tubing system: reducing T-connector immediately after the pump with ¼" tube and ½" tube, another reducing T-connector at the end of ½" tube
- Rubber caps to selective close off the ¼" and ½" ends of the reducing T-connector at the end of the ½" tube; a screw to cap the ¼" tube if needed.
- 2L measuring cup
- Tape measure
- Stopwatch
- Metal ruler
- Footswitch for safe operation of pump; power on only when switch is pressed
- Plug-in power meter to measure pump power

Safety:

Safety first is the motto for any experiment. The combination of water and electricity is inherently dangerous, so you should carefully plan your experiments. The aquarium pump is designed to operate underwater and the foot switch provides additional safety, but you should apply common sense during experiments: do not place unsealed electrical connections in areas where water may be expected. Furthermore, wet flooring can be slippery, so work neatly in a suitable environment.

Additional hints and requirements:

- Pump curve:
  - the ¼" tube can be used as a manometer to measure pump head, while manipulating the flow in the ½" tube;
  - various methods can be used to measure flow rate with the available tools, so you should consider accuracy of your measurements when you design your experiments;
  - pump curve should include data on pump efficiency;
  - think about the easiest way to manipulate flow rate through the ½" tube in such a way that you can measure it carefully.
- Split flow:
  - flow through both tubes simultaneously should be measured and compared to predictions you would make based on Chapter 13;
  - the plastic tubing may be considered "smooth".
- Friction coefficient:
  - according to Chapter 13, the head loss from fittings can be described as

  $$h_{L,f} = K_f \cdot \frac{v_p^2}{2g};$$

  your task here is to determine the value of K_f and the accuracy of the $h_{L,f} \sim v_p^2$ scaling if the flow is directed through the ¼" end of the T-connector at the end of the ½" tubing instead of flowing through the ½" end.

- General:
  - do not run the aquarium pump unless it is immersed in water; running it in air can damage the pump;
  - the lack of precisely prescribed experimental procedures is intentional, and a key part of the fun; you are welcome to ask additional questions, but your instructors will not tell you how to carry out the experiments in detail;
  - the lengths of tubing are not exactly the same for each kit, so you need to accurately report these parameters, as well as your kit number, in your report;
  - you need to return your equipment at the end of the project and obtain TA sign-off; if equipment is not returned following this protocol, you will receive no project grade;
  - with 4 group members, you have plenty of hands on deck to perform the experiments; make good use of these resources;
  - the report must contain a picture of all the entire group with the experimental set-up as proof that all members were participating in experimentation.

Project report due date: Thursday December 1, 1:35pm

ChBE 3210: Take-home Experiment
Summer 2017
Experimental Instructions

Objectives:
The take-home experiment has three key objectives/deliverables that must be addressed through a combination of experiments and data analysis:

1) **Determine the convective heat transfer coefficient *h* for cooling a warm object under various conditions (free and forced convection);**
2) **Compare free convection convective heat transfer coefficients for cooling and heating of the same object;**
3) **Estimation of the thermal conductivity *k* for nylon.**

The final product of the project will be a brief report (supported with appendices with raw data and sample calculations) that describes the experiments, data analysis and conclusions for each of these objectives.

Project evaluation:
The project grade rubric takes into account 4 elements:

1) **Equipment care (10%)** – state of equipment upon return; kit should be complete clean, dry and neatly organized; any equipment issues must be reported upon return, unreported damage will be penalized; self-reported issues will be treated much more leniently, provided that they are not the result of gross negligence.
2) **Quality of experimental data (30%)** – although there is no “right answer” in terms of data, well-planned experiments yield high-quality data that enable meaningful, strong conclusions to be drawn; on the other hand, poorly conceived experimental plans do not allow you to perform the type of analysis that is needed.
3) **Quality of analysis (30%)** – even excellent experimental data is useless without thoughtful analysis to extract all available information.
4) **Clarity of report (30%)** – the final report should not exceed 10 pages (incl. figures, but excl. supplementary information in appendices like raw data and sample calculations); for each objective, you must describe the experimental method, report results and analyze the data. The reported results must be in the units that are specified on the Excel template for data reporting; not following this guideline will result in deduction of points for this part of the report.

The report should be divided into three subsections, each addressing one of the project objectives. This is a technical report, so clarity and effectiveness of your writing is key; no need for a prosaic masterpiece. Basic grammar and spelling should be correct, though, in order to not distract the reader unnecessarily.

Equipment:
The following equipment is made available to you in a labeled 5-gallon bucket for storage (note kit number):

- Insulating foam mat as thermally insulating surface to perform experiments on;
- Two cylinders (aluminum and nylon; 2” diameter and 2” length) with predrilled hole patterns; 3 holes are 1” deep, 2 each are ½” and ¼” deep, resp.;
- Handheld thermometer unit (Omega HH501DK) with 4 connections for type-K thermocouple probes; the unit can display data from each thermocouple, or selected temperature differences, by using the rotary dial; it also has a hold function for enhanced precision in data collection;

- Four sheathed thermocouple probes for simultaneous measurements of temperature at multiple locations;
- Vaseline to improve thermal contact between thermocouple probes and holes, and to provide some friction to stop the probes from sliding out;
- Short pieces of silicone tubing to place around the thermocouple probes for insulation near the cylinder surface (may or may not be needed);
- Miniature desk fan with variable fan speed and USB-rechargeable battery (incl. USB cable); the air speed for each speed setting is not known, but if fan speed and distance away from the fan are specified, the air speed in your experiments should be reproducible;
- Stopwatch;
- Metal ruler;

Safety:
"Safety first" must be the motto for any experiment. For this project, the potential hazards are limited. Controlled heating and cooling of the cylinders is the main concern. Immersion in hot/warm water is the preferred heating method and you should be careful when handling hot water and heated cylinders.

Additional hints and requirements:

Objective 1 - Heat transfer coefficients

- Use the aluminum cylinder to measure the convective heat transfer coefficient for cooling of a warm cylinder in the surrounding air; explain in your report why the aluminum cylinder is the preferred choice for this objective.
- Determine h (in $W/m^2 \cdot K$) for free convection and <u>two</u> air velocities in forced convection; comment on observed differences.

Objective 2 - Free convection heating vs. cooling

- In Chapter 20 of the textbook, it is discussed that the h-values for heating and cooling of the same object via natural convection are quite different; perform experiments that enable you to investigate the significance of this effect for heating and cooling of the cylindrical objects.
- Report the ratio (dimensionless) $h_{cooling}/h_{heating}$.

Objective 3 - Thermal conductivity of nylon

- Using the h-values obtained for aluminum, perform cooling experiments on the nylon cylinder that enable you to estimate its thermal conductivity, k_{nylon} (in $W/m \cdot K$).
- Exact determination of k_{nylon} will be difficult, but you should be able to make a reasonably accurate estimate; you should comment on the accuracy of your estimate and how it could potentially be further improved.
- Note that this objective is not a simple task, especially if you want to do it accurately. All the necessary information is available in the textbook, but you need to plan your experiments carefully and the analysis process will likely require iterations. It is therefore advisable to find an estimated range for k_{nylon} from the literature before you start your experimental planning and data analysis.

General

- It will be important to carefully document the relative position of the fan and cylinders during your forced convection experiments; marking the location of various objects on the foam mat is advisable (*e.g.* small pieces of tape).
- When all 4 thermocouple probes are used at the same time with the handheld unit, the wires easily entangle, so that it becomes difficult to identify which thermocouple probe is connected to which inlet port; labeling your probes with pieces of tape could therefore be helpful.
- Thermocouples are sensitive tools and should be handled with great care; do not sharply bend the connecting wires, pull on the plugs and not the wiring to unplug a thermocouple, and make sure not to bend the shaft containing the thermocouple probe; each probe costs roughly $30.-; after use, place the probes back in the protective casings in which you received them.
- The hole patterns in the cylinders have been drilled in such a way that you can minimize interference between the thermocouple probes and the air flow.
- For greatest efficiency and accuracy, experiments should generally be carried out while simultaneously using multiple thermocouple probes. Cooling and heating of the cylinders takes a little time, so plan the "runs" carefully in order to prevent undesirable repeats.
- Check the calibration of your handheld thermometer and all thermocouple probes before you get started with your experiments; ice water (a mixture of melting ice and water) is an excellent calibration medium, because its temperature is known exactly: the melting point of ice.
- Monitor the air temperature during experiments and avoid disturbances of the local air temperature; laptops, human bodies, etc. can all affect the local temperature quite significantly, so be deliberate in your experimental planning and equipment placement.
- Experimental data is best presented (and analyzed) by creating <u>graphs</u> (not just tables) and using data fitting of the <u>entire</u> data set; this helps you to identify potential deviations between theory and experiments, and it generally provide more accurate determination of the desired parameters.
- You need to return your equipment at the end of the project, including the "equipment status" form, and obtain TA sign-off; if equipment is not returned following this protocol, you will receive no project grade.
- With 4 group members, you have plenty of hands on deck to perform the experiments; make good use of these resources.
- The final report must contain a picture of the entire group with the experimental set-up as proof that all members were participating in experimentation.
- Mandatory report filename format: "*ChBE3210_Su17_Project_FinalReport_GroupXX.pdf*" with XX replaced by group number (e.g. 01 or 11; see Google Doc for group number assignments).

<u>Final report (hard copy and electronic) due date</u>: Wednesday 6/21 at 11:59pm
(electronic submission time will count; hard copy cannot deviate from electronic version)

Georgia Institute of Technology

Professor David Sholl
John F. Brock III School Chair
School of Chemical & Biomolecular Engineering
Georgia Institute of Technology
311 Ferst Drive, N.W.
Atlanta, Georgia 30332-0100 U.S.A.

January 26, 2018

Dear Joyce,

I am writing to enthusiastically nominate Prof. Victor Breedveld for the CTL Innovation and Excellence in Laboratory Instruction Award on the basis of the wonderful work he has done to introduce experiential learning in ChBE core undergraduate courses. The large number of students in ChBE and the inflexible nature of our curriculum makes increasing hands-on experiences for our students very difficult. At the same, many of us in ChBE recognize the incredible value that hands-on experiences have in student development. A traditional solution to this issue would be to add a new lab-oriented course; unfortunately our curriculum does not allow this.

Over the past several years, Victor has implemented two innovative solutions to the dilemma I mentioned above. Specifically, he has introduced hands-on experiential learning into two required junior level *lecture-based* ChBE classes. In one case, he has developed activities in which the class performs live experiments with heat exchangers via a video-feed with the ChBE unit operations lab. Victor has worked on many aspects of this approach, both practical and pedagogical, to make it a productive exercise for the students. This concept of having students participate in collection of real experimental data while being located in their regular classroom and then working with the resulting data and connecting it to the concepts being covered in the their lectures is a powerful one. Critically, it is also a highly scalable approach. Prof. Breedveld has already identified additional equipment in our undergraduate Unit Operations Lab that can be used in additional experiments of this kind in other lecture-based classes and has made all of his approaches suitable for easy adoption by other ChBE faculty.

In a second effort, Prof. Breedveld developed a series of take-home "bucket" experiments that are now used in two junior level ChBE lecture courses, ChBE 3200 and ChBE 3210. These experiments are now used by more than 200 students per year. In these experiments, small groups of students receive a 5 gallon bucket containing various pieces of equipment and are given minimal instructions about how to assemble the equipment and perform experiments. A set of exercises accounting for 10-12 hours of total time are given to the students associated with performing hands-on experiments, data analysis and writing a short report. These experiments are now being used every time these courses are taught by any instructor, so Prof. Breedveld's vision and perserverance is making a positive impact on every single ChBE student at Georgia Tech.

The activities I mentioned above are emblematic of Prof. Breedveld's deep commitment to undergraduate education and his willingness to try new things. The concept of including "meaty" hands on activities within our lecture classes has now been proven and is becoming deeply embedded in our School's culture. I anticipate that efforts of this kind will expand to other classes in our curriculum and that as a result, the skills and confidence of ChBE students over many years will be enhanced. Because of these efforts, Prof. Breedveld is an ideal candidate for this award.

Sincerely,

David Sholl
Chair, School of Chemical and Biomolecular Engineering
Georgia Institute of Technology

Hang Lu, Ph.D.
Love Family Professor
School of Chemical & Biomolecular Engineering
Atlanta, Georgia 30332-0100 U.S.A.
Phone: 404-894-8473; Fax: 404-894-4200
Email: hang.lu@gatech.edu

January 28, 2018

To the Awards Committee:

I am writing to give my enthusiastic support to the nomination of **Prof. Victor Breedveld** for the *CTL Innovation and Excellence in Laboratory Instruction Award*. Victor's recent innovation and implementation of experimental components in his courses have improved the experiential learning of students as well as other instructors' approach in teaching the courses.

Victor and I have taught the same undergraduate Transport courses (CHBE 3200 and 3210) for many years. These courses involve many abstractions of physical phenomena, and students often struggle to visualize and translate these mathematical constructs back into physical and engineering intuition. We often use classroom demonstration or videos to help students. Victor's recent efforts have gone further by introducing live and hands-on experiments, which help students build physical intuition and significantly enhance student engagement.

Victor's first major innovation, live in-class experiments, tackles the challenge of bringing a hands-on experiment to a large audience. For these experiments, he would use a video chat with a lab technician in our Unit Operations teaching lab to carry out an experiment from the classroom during a lecture period. Students would suggest experimental parameters, e.g., configuration of heat exchanger, and they could see the result live through the video. Victor has designed the experiment carefully so that meaningful results can be obtained within a reasonable time to fit in a lecture period. The experiments are used not only to demonstrate the use of concepts learned in class, but also to show that real measurements have uncertainties and deviation from theoretical equations.

The second major addition Victor made to the courses is the use of take-home sets of experiment, which we call "bucket experiments" because the pieces of equipment fit in a bucket that students can bring home to run experiments on their own. So far, Victor has designed two such bucket experiments: one on fluid flow and another on heat transfer. Victor has used these experiments when he was the instructor for these courses. I have also, in collaboration with Victor, implemented these bucket experiments when I was an instructor for one of the courses, and am intending to use it again this semester (Spring 2018). The fluid flow bucket experiment consists of an aquarium pump, a set of plastic tubing, and simple measurement devices such as a beaker, a small power monitor; one bucket costs less than $50. These pieces - along with some ingenuity on Victor's part in designing the experiments – were sufficient for students to make measurements of, for example, pump efficiency and viscous losses in water flow through a tube.

Students enjoyed these experiments because not only could they see directly concepts learned in class, but they also could try – even better, play with – different configurations and parameters and make investigations and discoveries on their own. Students often relate stories of different ways they have thought about and tried the experiments to me and the teaching assistants, and all with a smile or laugh on their face. Another thing that I appreciate in Victor's design of the experiment is his care in balancing this freedom to play and discover with the safety of the students. For example, a nice touch is the inclusion of a foot / pedal switch that allows students to avoid handling the electric pumps with possibly wet hands during the experiment; the switch also allows quick shut down of the electric pump. After the experiments, students submitted a report to describe their experience and their analysis of the data. My observation is that after working on these bucket experiments, they seem to have a better grasp on the concepts related to pumps, piping networks, and frictional loss.

In summary, I strongly believe that, through these initiatives, Victor has demonstrated innovation and excellence in providing experiential learning for the students in these classes. I hope you will agree with me that he is truly a worthy recipient of the Innovation and Excellence in Laboratory Instruction Award.

Sincerely,

Hang Lu

Miss Mandy Salmon
Msalmon6@gatech.edu

January 27, 2018

To whom it may concern:

I am writing to enthusiastically recommend Dr. Breedveld for the CETL “Innovation and Excellence in Lab Instruction” award. Dr. Breedveld taught me Transport Processes I and II. Transport was a class that really challenged me; the concepts were new, but also Dr. Breedveld pushed me and helped me learn more about myself as a student. Dr. Breedveld gives ample practice for grasping knowledge conceptually, in addition to providing in-class demonstrations and experiments that elucidate in-depth knowledge on a topic by working with a concept in action and learning to work better in a group. One example of the way Dr. Breedveld cemented concepts into our minds were his bucket experiments. With his bucket experiments, I worked with a team to analyze pump mechanics in Transport I and heat transfer in Transport II. I distinctly remember later having a conversation with a fellow intern at ExxonMobil about sizing a pump. He showed me a pump curve and seemed to be a bit confused. When he told me he had already taken a Transport Processes class, I was shocked. I was able to easily explain to him how to read the pump curve; after all, it’s hard to forget how to read a pump curve when you have performed experiments to construct your own, a project that Dr. Breedveld had pioneered in the Chemical Engineering department the semester before my internship.

Besides his excellent teaching techniques, Dr. Breedveld has a knack for keeping his students engaged in his lecture. Perhaps it is his ability to ask us simple real-life questions based on applicable principles that initially stump us, or his high-quality lecture notes, or the clever jokes he intersperses between the equations and principles that he writes on the board. Although he initially intimidated me, as a professor with so much knowledge and experience, I quickly learned how much he cares about his students. Dr. Breedveld was always eager to explain a concept to me or my fellow classmates in office hours, and he impressed me by not only answering my questions, but also extrapolating the questions to bigger-picture concepts that helped me understand why a given problem was relevant or necessary to learn at all.

Dr. Breedveld’s classes were highly structured, with excellent notes, study guides, and equation packets that I still use, as a senior chemical engineering student, in my classes today. Last semester, for example, I frequently referenced his notes on packed beds during a Unit Operations experiment with a fluidized bed. I don’t think I realized how lucky I was to have Dr. Breedveld as my Transport instructor until I began to work with students in other classes who had taken Transport with a different instructor. Where their knowledge of transport principles was fuzzy, I clearly remembered the mechanism of a heat transfer principle from our bucket experiments or an application of Archimedes’ principle from a Learning Catalytics question about the change in water level of a lake after dumping water from a boat (the water level, surprisingly, does not change). Dr. Breedveld has a passion for emphasizing the conceptual, and as a professor he transcends beyond the traditional plug-and-chug mechanics involved with so many of the classes in our curriculum to not only tell, but also show us the way that Transport is relevant in our lives as engineers.

Sincerely,

Mandy Salmon

Dr. Breedveld is heralded by many of my peers to be one of the greatest conceptual teachers in the ChBE department. He has an aptitude for developing and involving students, and above all pushes students to make wise decisions under stress. Breedveld always pushed the envelope by asking tough questions in class; the questions were not necessarily easily answerable even having read the material beforehand. This encouraged the students to not only read ahead of time, but also start thinking about the possible uses of the material. Since the questions did not necessarily have a single answer, he often left the floor open to debate until the entire scope of the concept was realized. This was a great strategy for enhancing both critical thinking and modeling skills necessary for problem solving in future classes and in the real world.

Most of the concepts taught by Dr. Breedveld could be illustrated using the whiteboard. However, one of the better classes in recent memory was when he showed us in real-time how a heat exchanger worked using Skype. As a visual learner, this not only accelerated my own learning experience for Transport, but also gave me a basis for my heat exchanger lab in Unit Operations. I had to compare two different heat exchangers with two different flow configurations each. Coincidentally, the heat exchanger report was my group's best grade out of all my Unit Operations lab reports and posters. The Skype call wasn't just a visual aid, but also an in-class experiment to keep people involved. The students called upon would have to be ready to remember their probe's temperature so that it could be recorded for future homework. We also applied maximum and minimum flowrate boundary conditions to determine its effect on heat transfer. This was particularly useful, because we could then apply our knowledge to an array of conditions.

Dr. Breedveld also experimented with my class by offering more of a hands-on approach to learning by incorporating group projects. It is important to note that I did not have many group work projects up to this point in the curriculum. The two transport projects were the first projects that required in-depth collaboration, writing, researching and physical handling skills. I witnessed many students struggling at first because they did not know where to begin after just being given a bucket of equipment, some of the basic concepts, and a couple of problem statements. Other students were also having issues with team kinetics and had to iron out those issues. In the end I believe everyone grew from these experiences, and by only focusing on one project in a semester this helped develop a model for handling reports for Unit Operations, Process Control and Senior Design.

Overall, Dr. Breedveld was very effective at developing his students' fundamental understanding, application, analysis and reflection of the concepts for Transport I and II. He provided opportunities for students to discuss, investigate and solve real-world problems as a team and on an individual basis. I am a firm believer in Dr. Breedveld's ability to comprehensively develop his students in a positive, yet challenging environment. An environment designed to keep you attentive, involved, but above all happy to know that you are truly being developed into a quality Georgia Tech engineer. With all of this in mind, I would strongly recommend Dr. Breedveld to be recognized for his excellence in lab instruction.

Best Regards,
Matthew Zwolinski
902-376-410

Dear CTL Awards Committee,

I am writing this letter in support of Dr. Victor Breedveld's nomination for this year's Innovation and Excellence in Laboratory Instruction award. I have taken two classes with Dr. Breedveld, both Transport Processes I and II, which allowed me to observe Dr. Breedveld's teaching style, interactions with students, and the take-home experiments and remote lab activities he devised. Through these experiences I can confidently say that Dr. Breedveld has my full support in his nomination for the CTL Laboratory Instruction Award.

In both classes I took with Dr. Breedveld, he used take-home experiments to facilitate learning of some main concepts from class. The experiments allowed us to make predictions about real world systems, and then run our own experiments to see if the results matched our expectations. The Transport I project used a small aquarium pump to measure its performance and analyze the flow of different sets of tubing. The Transport II project used two objects made of different materials to measure their thermodynamic properties under different conditions. While these projects gave us clear goals for the information we would gather, the methods for getting that information were left to our discretion, with a little guidance from Dr. Breedveld. This allowed us to work with our groups and decide what the best way to measure each property, and then design the experiments in a way that minimized the experimental error. This required us to not only dwell on our conceptual understanding of the theories we learned in class, but to also use our intuition in developing reliable experimentation methods with our group members. These projects were also valuable as good introductions to writing formal lab reports. In freshman chemistry classes we were introduced to lab reports, however in our 4000 level classes the lab reports required of us are much more detailed. Dr. Breedveld's projects gave students the opportunity to be exposed to that style of writing early on, which was very helpful for later classes.

In addition to the take-home projects, Dr. Breedveld also had a "remote" lab experiment with us when learning about heat exchangers during Transport II. This again was an opportunity to use the theoretical knowledge we gained in class to predict real-world phenomena. As a class, we would make predictions about how the heat exchangers would perform based on what we had learned in class. The experiments were then carried out in the lab, so we could see the results over Skype. This process gave more of a visual tool for seeing how these real systems perform in comparison to the idealized systems that we use to do problems in class. This experiment also gave a good visual example to draw on, which helped a lot when looking at similar problems in later assignments and exams.

Dr. Breedveld shows that he cares about the success of students and ensures that they leave his class with a good understanding of the material. Through review sessions, office hours, and answering questions after class, Dr. Breedveld makes a serious effort to be available for helping students. Additionally, the supplemental activities like the take-home experiments and Skype heat exchanger activity show his willingness to try new ideas to engage students in their learning. I believe that Dr. Breedveld has shown very clearly that he is deserving of the CTL Laboratory Instruction Award, and I know that there are many others that believe this too.

Best Regards,

Zach Hoffman
Georgia Tech Class of 2018

Dear CTL Awards Committee, Jan 30, 2018

I am writing to strongly support Dr. Breedveld's nomination for the 2018 Innovation and Excellence in Laboratory Instruction Award. I have known Professor Victor Breedveld for two years since I was a student of his in Transport Processes I and II. I cannot think of a person more deserving of this award. Dr. Breedveld is passionate about teaching and an expert in creating effective conventional and unconventional curriculum. He has devoted considerable time and energy to improve his teaching, evaluate the outcomes of his teaching practices, assess students' opinions of the class and the course content, and improve student engagement.

For example, Dr. Breedveld developed two take-home experiments to show and engage student the practical examples of the theoretical work that had been taught throughout the semester. He also conducted a Skype in-class heat exchanger experiment, which in addition to the take-home bucket experiments, caused students to participate fully and the class became more interactive. By utilizing a different method of teaching, he allowed students with alternative learning styles to better grasp the materials.

The two bucket experiments were designed to investigate, analyze, and solve real world problems using the knowledge gathered from the course concepts and the discussions held in class. The experiments involved simple equipment and were open ended, allowing students to use their surroundings as a tool to guide and aid the completion of the projects. These three experiments helped me personally in my future lab courses, such as Units Operations, since I was able to reflect back and investigate how to solve the problems faced in the lab setting.

Dr. Breedveld believes in the potential of every student and I have seen him repeatedly help students succeed. He is fair to all of his students, has high expectations, and is approachable. Dr. Breedveld has been an excellent mentor to me and to his other students. In sum, he is a dynamic professor and is most deserving of the Innovation and Excellence in Laboratory Instruction Award.

Sincerely,

Rozhin Parvaresh