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# 1) Abstract

This Engaged Practices Innovation proposal seeks to meet fundamental needs for the successful transition to an active learning experience in Physics at UVM. Future introductory courses will be focused on small group interactions and refined expression of reasoning, where students engage daily with conceptual, numerical, and hands-on physics problems. This transition will require two key components: 1) additional equipment to accommodate the new experiments and hands-on activities for 30 groups simultaneously, compared to 6 in our conventional lab sections, and 2) increased student-instructor interactions required to support and foster written and oral expression of conceptual reasoning. We propose implementing an innovative Undergraduate Learning Assistant (ULA) program,[1] where experienced undergraduates, graduates, and the instructor facilitate in-class discussions and activities. These practices support collaborative work, writing, revising, and expressing conceptual reasoning; two of the high-impact educational practices identified by the Association of American Colleges & Universities.[2]

# 2) Introduction

We will transition our department to a pedagogically up-to-date experience. This is motivated by a preponderance of evidence showing concrete improvements in learning outcomes upon implementation of active learning.[3-12] In a 2012 review, Meltzer and Thornton describe these methods: "(1) they are explicitly based on research in the learning and teaching of physics; (2) they incorporate classroom and/or laboratory activities that require all students to express their thinking through speaking, writing, or other actions that go beyond listening and the copying of notes, or execution of prescribed procedures; (3) they have been tested repeatedly in actual classroom settings and have yielded objective evidence of improved student learning."[12] In the STEM complex Innovation wing, the Physics Department has designed a 90-seat active learning classroom based on best practices in the field.[3, 6] Recent faculty hires have been focused on recruiting teacher-scholars with extensive experience as instructors and students in active learning environment. The department is fully committed to this change, and to documenting and disseminating the measureable improvements in our students' learning.

#### 3) **Project Description**

The group-based active learning Physics classroom will have 3 groups at each of 10 tables. A typical class will consist of mixed difficulty group problem solving with minor mini-lectures from the instructor to focus the discussion. Varied in nature, the activities will include conceptual tutorials requiring written expression of reasoning, analytical and numerical problem solving, computational simulations, and hands-on experiments. The plethora of activities oriented around a single physics concept reinforces conceptual understanding and encourages participation from diverse individuals. The department will eventually transition all introductory physics courses to the group-based active learning format, with a phased rollout to minimize potential missteps [13, 14] and tailor to target audiences. The calculus-based physics sequence for science majors will transition Fall 2019/Spring 2020. Building on our experience, we'll then transition the algebra-based introductory sequence; then turn to the introductory service courses for CEMS.

#### 3.1) Experimental equipment

Our conventional lab equipment is designed around 6 groups of 4 students. Successfully implementing our active learning format will require experiments that reinforce conceptual and analytical reasoning on one core topic within a short session. New experiments will fit within 15 – 20 minutes, and 30 groups must be able to work simultaneously. Therefore, we need manipulables that are robust, provide rapid feedback with easy user interface, and cost significantly less per unit than current equipment.

Building on our internal testing, we've selected several tools for this new model; such as the iOLab unit, a USB compatible device with sensors for kinematics and electronics. It will enable at least fifteen different experiments. Similarly-versatile equipment will be used to explore concepts such as projectile motion (BeeSpi V photogates), forces and vectors (push-pull scales), rotational dynamics/angular momentum (bicycle wheels). We foresee a modest amount for custom parts that need to be machined in the Physics machine shop.

## 3.2) Undergraduate Learning Assistants

This project will support the implementation of the ULA program in the introductory physics courses, as developed by the University of Colorado's Physics Education Research group.[1, 15] Once fully implemented, undergraduates in their 2<sup>nd</sup> to 4<sup>th</sup> year will join professors and graduate TAs as peer-instructors in the Physics Active Learning environment. In transitioning to this goal, we will conduct alternating experimental tutorial and active-learning sessions along with traditional laboratories during the 2018-19 academic year. We request support for four ULA stipends for both

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Fall 2018 and Spring 2019, allowing one ULA per lab section during conventional labs and two per section during active-learning activities. The program will greatly improve UVM's recruitment and retention of top STEM students as peer-instruction is known to decrease student attrition.[16, 17] It will provide a pathway to a minor, B.A., or B.S. in Physics for future high school teachers and make our Physics B.S. students more competitive when applying for PhD positions. Perhaps most important, it will improve the overall quality of our introductory physics instruction and learning outcomes for both majors and non-majors.

#### 4) Expected Impact

We expect three measureable impacts to result from our transition to the group-based active learning course format. 1) Significant improvement in understanding and expression of reasoning with respect to core physics concepts in introductory courses. 2) Increased participation from women and underrepresented minorities. 3) More trained physics educators participating in K-12 education. While physics is typically taught in  $10^{th} - 12^{th}$  grades in U.S. high-schools, a significant barrier for underrepresented groups is lack of early exposure and preparation in science.[18] We consider preparation of any K-12 teacher with advanced physics pedagogy methods to directly address a core societal problem.

#### 5) Assessment Plan

Assessment will follow established best and commensurate practices in the field, such as pre & post testing with the Force and Motion Conceptual Evaluation (FMCE) for introductory mechanics, and the Brief Electricity and Magnetism Assessment (BEMA) for electromagnetism.[19] Our data will be uploaded to the secure and confidential Physport.org assessment database; allowing us to compare our outcomes to national averages.

Our innovations' impact on participation in physics by underrepresented groups and preparing physics educators at the K-12 level will require time to assess. Progress toward student learning achievements will provide significant information within the first few years, as we teach over 400

students per semester. We will track participation in our major, minor, graduate programs, and the ULA program each year, from underrepresented groups, including women. Our progress will be assessed by comparing to regional, national, and our own historic averages. We will additionally monitor the number of participants who go on to participate in teacher certification programs; expecting it will take years to conclusively measure these metrics.[20] Nonetheless, we will use our assessment in publishing a summary paper on the effective implementation of our active learning classroom in the *American Journal of Physics*, and a follow-up paper as the implementation and impact of the program becomes clear through its lifetime. Furthermore, we will stay involved in the ongoing national discussion through presentations at national and regional conferences.[21] Our results and best practices will be shared locally, through partnerships in the STEM complex and across disciplines with ongoing participation in the Center for Teaching and Learning's programs such as the Scholarship for Teaching and Learning (SoTL) Pilot.

### 6) References Cited

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#### 7) Proposed Budget

As detailed in the proposal, we are requesting funds to support 8 undergraduate learning assistants (ULAs), 4 during the Fall of 2018 and 4 during the Spring of 2019, and to purchase the necessary equipment for hands-on group activities and in-class experiments. 4 ULA's per semester will support one ULA per lab section during conventional labs and two per section during active-learning activities. Equipment purchases allow for 2 or 3 units per group (30 groups) plus extra for instructor use, troubleshooting, and replacement. Bicycle-wheels are purchased at one per table (10 tables) as their size requires more controlled in-class use. The below table shows an itemized budget with the expected expenses and the department cost-share.

The department of physics will contribute \$4,000 towards the purchase of teaching lab equipment for the group-based active learning classroom during the 2018/2019 academic year. It will contribute an additional \$4,000 in each of the two years following the completion of this EPI project to ensure adequate equipment is available and maintained for the full introductory physics curriculum. These contributions in the following years are not listed in the cost-share table below, as they are beyond the duration of the EPI project. During the AY 18-19 active learning trial run, we will assess the need to transition the first-year introductory physics sequence to a lab-fee model, in order to maintain equipment, depending on the rate of loss and damage. In order to sustain the ULA program beyond the duration of the EPI grant, the Physics Department will design a K-12 physics teaching track, including options to participate in the ULA program for credit. Pre and post surveys of the ULA participants will gauge whether the for-pay, for-credit, or a hybrid model is most appealing to the various UVM undergraduate groups who may be interested to participate.

	ULA's needed AY F18-S19	Semester stipend per ULA	Total ULAs Stipends
Undergraduate learning assistants	8	\$800.00	\$6,400.00
Equipment	No. of Units	Unit price	Total Price
iOLabs ( <u>https://www.macmillanlearn-</u> ing.com/catalog/preview/iolab )	70	\$100.00	\$7,000.00
Bicycle Wheels ( <u>https://www.ar-borsci.com/nsearch/?q=bicy-cle+wheel</u> )	11	\$130.00	\$1,430.00
Photogates ( <u>https://www.ar-</u> <u>borsci.com/beespi-v-photogate-</u> <u>timer.html?ff=4&amp;fp=620</u> )	70	\$45.00	\$3,150.00
Push-pull spring scales ( <u>https://www.teacher-</u> source.com/product/142/ )	100	\$10.00	\$1,000.00
Table Clamps (https://www.pasco.com/prodCata- log/ME/ME-8995 aluminum-table- clamp/index.cfm )	70	\$50.00	\$3,500.00
Machine shop items (wood, metal, stock, weights, etc.)	1	\$500.00	\$500.00
		Total costs	\$22,980.00
		Dept. cost-sharing	\$(4,000.00)
		EPI funds requested	\$18,980.00

# The University of Vermont

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April 12, 2018

Re: Support to "Group Based Active Learning in Physics Program"

To whom it may concern:

I would like to express my strong and enthusiastic support for the proposed "Group Based Active Learning in Physics Program". As the proposal outlines, the physics department in the University of Vermont will fundamentally change the traditional teaching methodology from "lecture/lab structure" to "group based hand-on active learning pedagogy". In the Innovation Building of our STEM Complex, a new classroom with 90 seats has been designed based on the MIT Technology Enhanced Active Learning Room Concept. Our new recruited faculty members who have active learning experience will be in charge of the program. We strongly believe this new endeavor will excite our students and make them grasp the fundamental concept much better than the old method. The proposed program will: (1) Significantly improve the teaching efficiency, (2) significantly improve the quality of undergraduate education and research in physics and all STEM disciplines. The active learning is widely accepted in the science and technical fields. We believe that the University of Vermont will be able to attract, retain, and successfully train undergraduate students by the new pedagogy. Given the steady rise of the STEM undergraduate student population at the University of Vermont, we should provide them the best possible education and future employment opportunities in our unique small premiere research university environment.

As a chair of the department, I certainly will do my best to make it a reality in the near future.

Sincerely and with my best wishes

Gumm/

Professor Junru Wu Chair, Physics Department University of Vermont





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April 12, 2018

Prof. Jim Vigoreaux Office of the Provost 348 Waterman Building University of Vermont Burlington, VT 05405

Dear Jim,

The College of Arts and Sciences is delighted to support the EPI proposal lead by Prof. Vanegas to facilitate the Department of Physics's transition to an active learning environment. This is an important and challenging transition that will allow the department to fully utilize the facilities in Innovation.

Sincerely,

Rory Waterman