FY14 Innovations in Teaching with Technology Awards: Enhancing Student Learning in Transport Phenomena Related Engineering Courses

FY14 Innovations in Teaching with Technology Awards

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<td>Department(s):</td>
<td>Mechanical and Industrial Engineering</td>
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<tr>
<td>Funding Awarded:</td>
<td>$25,000</td>
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The Mechanical and Biomedical Engineering (ME and BME) disciplines are the highest subscribed and fastest growing undergraduate academic programs in the college of engineering, numbering approximately 865 students (44% of engineering undergraduates). In this proposal, we seek to develop a powerful and intuitive user interface for an existing world-class thermal and fluid flow solver, and seamlessly integrate these powerful tools into formal and informal teaching activities within these engineering programs. This interface will be built so students can easily access and use a well developed computational code called pELAFINT3D.

Students will be provided access to the code from PCs and laptops on and off campus. It is expected that such a software tool will have a major impact on student learning and exploration of modern pedagogies – such as TILE-based teaching and “flipped classrooms” – in ME and BME courses covering a wide range of fluid, thermal and mass transport phenomena (Fluid Mechanics, Heat Transfer, Transport Phenomena, and Cardiovascular Fluid Mechanics and Circulatory Implants Design). In addition, student access to this tool will significantly expand undergraduate students’ capacities to conduct and learn from independent research and open-ended course projects. Professors Buchholz (JB), Vigmstad (SCV) and Udaykumar (HSU) have previously collaborated on related research proposals and publications. The proposed software will facilitate collaborative teaching opportunities because engineering courses involving laboratory experiments (taught by JB), design (taught by SCV and HSU) and theory can use computations to supplement learning. With the proposed graphical-user-interface-driven computational facilities, they can bring together their expertise (thermofluids experiments, thermofluids computations and biofluid dynamics) to truly
advance education in a wide range of bio- and mechanical engineering courses, and to establish a model for implementation in other subject areas and disciplines.

Specific environments in which students can better engage in collaborative learning include the IIHR Fluids Workshop (http://www.iihr.uiowa.edu/iihrfluidsworkshop) established by JB, and through implementation of the technology in a flipped course. Professors Vigmostad and Udaykumar have been conducting engineering courses in a "flipped" TILE environment in recent years and the proposed software will be extremely useful in that setting. The emergence and ubiquity of portable and mobile devices allows for a radical change in pedagogy as well as technological interfaces to make available hand-held, touch-screen portals for scientific computation. Once the proposed software is tested, by extending the software through funding from external sources, we plan to develop the interface to be accessible through mobile devices such as Tablets and Smart Phone and other Mobile devices. We view these devices as becoming the norm for connectivity in the near future and enabling students to access the computational platform on such devices will vastly aid in their learning and understanding of the subject matter. Because Cartesian methods (as implemented in pELAFINT3D) eliminate the need for complicated grid generation and multi-step preprocessing to compute flow solutions, it will be possible to develop a mobile app that students can use in and out of the classroom to compute and understand more deeply thermal, fluid and biomedical transport phenomena. While initially the software will be used in engineering courses, as functionality improves and user comfort levels can be enhanced, the larger biomedical community – including medical trainees and doctors in training and practice – can employ the tool for educational as well as clinical applications. It is planned that the development of the user interface will be conducted over the Spring 2014 semester. During summer 2014 testing of the app will be performed by expert users (faculty and graduate students in HSU and SV labs). In Fall 2014 the facility will be test-launched in classes taught by HSU, JB and SCV and further improvements as necessary will be performed.

We will be using ubiquitous laptop and desktop PC devices to help students conduct virtual fluids and thermal transport experiments on the go, obviating space and computer access requirements. These calculations can be done in classrooms, labs, and other student spaces so that students can supplement classroom theory and discussion type scenarios with what-if scenarios, visualizations and enhanced understanding by conducting in silico experiments, in a range of mechanical and biomedical engineering courses.

The software will be tested initially in a limited number of courses taught by the faculty collaborating on this proposal. JB, SCV and HSU have taught these courses before and felt the pressing need for such a readily accessed computational platform. To assess the impact the faculty will conduct student surveys on the software and seek
How will it improve student learning?

Student self-assessment on the value of the software in enhancing their understanding/experience in the course. Data on student performance on specific questions/topics in past semesters will be examined against the data on the same in the semester in which the software will be launched. In the semester in which the software is launched particular topics will be picked on which students will be tested prior to and following use of the software. In 58:125 Biomimetic Fluid Dynamics, developed and taught by JB, undergraduate and graduate students learn principles of fluid dynamics and aerodynamics relevant to biological locomotion in air and water. While theoretical models provide fundamental insights, they are very limited in their capacity to model realistic biological and biomimetic flows. Introduction of the planned computational tool would have enormous benefits, as students could readily observe and explore the effects of modifications to wing or fin articulation, flexibility, and shape.

The software would also greatly enhance student capabilities in a major open-ended project assigned in the class, where students electing to conduct a computational study typically do not have suitable software options due to the complexity of the wing or fin motions they wish to investigate. In the Circulatory Implants Design Class (taught by Professor Vigmostad) for example students will be pre-tested on their understanding of flow behavior in external (cylinder, plate, wedge, other shapes) and internal flows (channel, step, bifurcation) as function of control parameters (flow speeds, geometric parameters). Then, following their use of the software proposed they will be post-tested to determine how their understanding has improved. In the Energy Systems Design course (taught by HSU) the learning objectives are for students to be able to analyze and design thermal systems where fluid and energy flows in various systems need to be understood. The proposed software will greatly aid student understanding on the nature and behavior of flows in pipe circuits, building envelopes and around obstacles, so that they can get a better understanding of the systems that they will be designing. In those courses, the students will be pre- and post-tested in a similar manner to that indicated above for the Circulatory implants course.

The thermal-fluid simulation software pELAF\INT3D that forms the basis for the proposal has been developed by HSU and SCV for the past several years. It is mature and has been used extensively as a research tool. Over this time several funded research projects have led to the development of the research code. Graduate students and post-docs are supported on those projects but their work is related to the scientific computation aspects and not to the user interface being planned. However, their insights and experience as users can be leveraged in the development process. In addition, once the proposed facility is developed, further grants from NSF and NIH are planned to extend the facility and to make the tool powerful and prepare it for wider use in teaching and research across campus. We view the proposed project as a seed towards further development of the tools. In time, we expect that the project will be a
collaboration between mechanical and biomedical engineers, but will draw from computer science, medicine as well as digital arts departments. pELAFINT3D, does not require the generation of complex body-fitted grids – typical of commercial fluid dynamics software packages – which would otherwise present a significant barrier to novice fluid dynamicists, and thus it is highly suitable for teaching purposes. The proposed package can be widely distributed to students to an extent prevented by commercial software licenses, and the software will also allow internal development of custom teaching features for integration and evaluation in participating faculty’s courses and labs. Students will also be able to import geometries generated using a variety of methods (CAD models, and 2D and 3D imaging modalities such as optical imaging, CT, and MRI) so that they can study complex and realistic geometries. JB has recently established the IIHR Fluids Workshop, a laboratory and student community for the pursuit of undergraduate research in fluid mechanics and related disciplines, and open-ended course projects. In its inaugural year, the Fluids Workshop has provided unprecedented access to modern, research-grade facilities and instrumentation for over 25 students in ME, BME, civil and environmental (CEE), chemical and biochemical, (CBE), electrical and computer (ECE) engineering, and the Belin-Blank Center, conducting research and course projects. The Fluids Workshop will provide the initial setting for students to apply the proposed software package in independent research projects, and in support of class projects across the college of engineering. To help facilitate student access to the software in the Fluids Workshop, funding for a desktop computer is requested – this computer will initially be used for software development.

The primary needs for completion of the project are funding to support an undergraduate student software developer, and some time for a graduate student who understand the pELAFINT3D architecture to assist the developer. In addition, a desktop PC will need to be acquired for the undergraduate developer. Upon completion of the project, this computer will be used in the Fluids Workshop as described above.

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<th>Rough estimate of costs</th>
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The budget estimate for the project is as follows:  
An undergraduate software developer (knowledge of Java and Python languages) at 10 hrs per week for 12 months = $500 per month * 12 = $6000.  
A workstation and other software and hardware peripherals for the developer = $5000.  
A ¼ time graduate research assistant (with expertise in the flow solver pELAFINT3D) to help the software developer = $14,000.  
Total = $25,000.