**Application for Diversity, Equity & Inclusion Innovative Initiatives Grants**

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**Abstract:** Whittier College serves a diverse set of undergraduates with a variety of preparation levels for introductory STEM courses. These courses serve large cohorts of students and are required for many majors and professional schools. Our goal is to develop a mobile application infused with machine-learning and educational data-mining (EDM) that will boost equity and inclusiveness in foundational physics courses. Based on published examples developed at other institutions, we will create a customized tool that will strengthen our students' skills and abilities. Diverse undergraduate experts in digital storytelling and design will drive and shape the digital presentation of content. Our application will include the voices, narrative themes, and imagery of the diverse students actually attending foundational physics courses. The result will be an open educational resource (OER) designed to foster equity and inclusion for Whittier College Physics students.

**Physics education at Whittier College represents a precious opportunity:** to engage and inspire students of color and women to a wide variety of scientific, mathematical, and engineering principles. A pervasive myth at Whittier College is that "STEM tends to be white and male-dominated." [1] *This is not true.* According to our institutional research, 25% of all white male Whittier College students select major in STEM disciplines, but represent just 10% of STEM majors at Whittier College (data selected for the period of 2019-2022). White men accounted for just 18% of all majors in disciplines tied to engineering, 10% of all KNS majors, and just 6.3% of all biology majors. Introductory physics students are mostly biology and biochemistry majors who plan to attend medical school, KNS majors who plan to attend physical therapy school, and engineering students.[2] Bolstering student success in these courses is intrinsically anti-racist, because this large group of students is on the pathway to join and diversify fields in medicine, biotechnology, and engineering.

Another myth is that "systems designed by white men" cannot "address the needs of students of color and women who are marginalized in STEM."[3] *Again, not true.* Consider a proof by contradiction: introductory STEM courses at Whittier College are "systems" often created by white men, so by this logic no students of color or female students should succeed in such courses. But many do, as evidenced by course evaluation data and in our learning outcomes. If they did not, a large fraction of introductory physics students would fail. Introductory physics instructors regularly attend American Associated of Physics Teachers (AAPT) conferences on teaching techniques for undergraduates. Currently, we are attending Cottrell Scholars Network webinars on *Inclusivity in Introductory STEM Courses*. In the first of this 3-part series, the speaker presented social science research that reveals how affirming the dignity of students builds a sense of belonging as a scientist. One major motivation for this proposal is to

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1 Though this quote is taken from the initial response to this grant proposal, the sentiment being shared has been shared informally in a variety of faculty forums.

2 Note that in the data period (2019-2021), there were $N$ = 530 students who took introductory physics courses. Student demographic data at the course-level was not available. Disciplines tied to engineering include physics, math, computer science, and the 3-2 program.

3 As your friend and colleague, I was astonished to read such a strong remark in the initial response to this proposal. We must always trust the goodness of colleagues' motivations.

affirm the dignity of students of color and young women by providing them with a tool designed for them by myself *and by their peers.* There are two underlying problems, according to research, for those that struggle in introductory physics courses. (1) They perceive themselves to be less effective at science despite having the same grades as others, and (2) when they do struggle with physics concepts, they must be helped in a way that affirms their dignity. We propose to develop a tool that helps them automatically by showing them that (a) they are not alone in their anxiety about physics courses, and (b) peers have built tools designed to strengthen their skills. According to the social science research, differences in self-efficacy vanish when one addresses (a), and addressing (b) through dignity-affirming peer-built tools should strengthen the students.

Currently, in introductory physics courses, students engage with self-designed laboratory experiments, group projects, and active-learning strategies that include peer-learning. These elements are used because Physics Education Research (PER) has shown them to be more effective than traditional physics teaching techniques [1]. One major reason we propose this new application in DEI innovation is the engagement of students of color and young women *before* they begin foundational STEM courses. Physics instructors already collect data on student performance during the introductory courses, which informs us on how well students' conceptual understanding shifts between the beginning to the end of the semester [2]. Similar to our post-doctoral experience with bridge programs for first-year students [3], we seek to *prime* the students via digital content.

This strategy serves multiple purposes. The first is to affirm the students' dignity and foster belonging. Students of color and young women often wonder why the instructor "is not like them." By infusing the digital content with the voices and identities of their peers, and avatars created by their peers, the incoming students' dignity and identities will be affirmed in advance to foster a sense of shared belonging in the course. Our current strategy for fostering belonging in *Calculus-Based Physics I* (PHYS150) places the instructor's cohort of first-year advisees in the same sections of PHYS150 and INTD100 (College Writing Seminar). The digital strategy proposed here is extensible to all introductory physics courses. The second purpose for such a digital instructional tool is to sharpen and refresh the students' skills before the course begins. This strategy allows the instructor to tailor precious course time for the needs of the diverse population of students. Online physics homework systems already give some insight, but the data is collected *during* the course and contains no demographic data [4]. Gains in equity could be larger if we could tailor the course to people of color and young women *before it began*.

**We propose to enhance student belonging and learning by creating an application that combines digital storytelling with machine learning.** Physics instructors already work with staff from Wardman Library to help infuse our courses with training in digital storytelling (www.diglibarts.whittier.edu), so our students learn to present the results of self-designed scientific experiments to their peers using tools like WeVideo (https://www.wevideo.com). Within the Math and Physics departments, we have experience using machine-learning techniques [5, 6]. Further, the literature on educational data mining (EDM) contains a plethora of examples used to understand undergraduate STEM learning patterns [7]. An example of such an application using this two-pronged strategy for language learning is DuoLingo (https://www.duolingo.com), in which digital storytelling is used to welcome and strengthen the learner in stages. Learners of all backgrounds are affirmed through the visual storytelling aspect of the application, and their skills are strengthened incrementally such that the user feels empowered, rather than deficient. These ideas are at the core of this proposal. Finally, the EDM literature also recognizes that the earlier struggling students are identified and aided by the instructor, the better their outcomes [9]. Several examples of such digital tools have been created specifically for STEM courses [10,11]. Our hypothesis is that the digital storytelling aspect will raise student engagement by relating the content to their own experiences. One final point about the tool we propose: this tool is not based around any "deficit model" of student achievement. Rather, as we argue above and below, this strategy focuses on building strengths and building belonging within introductory STEM courses. To this end, more data from the *Inclusivity in Introductory STEM Courses* is relevant.

In the second of the 3-part series, *Inclusivity in Introductory STEM Courses* through the Cottrell Scholars Network, the speaker discusses self-efficacy and long-term success in STEM fields for women and people of color. If our proposed tool could show the students (anonymously) that they are not the only one who gets wrong answers initially, self-efficacy gaps tend to vanish [8]. Thus, it is important to note that any such data collection the tool might perform will be anonymous. Thus, the tool we propose actually has nothing to do with so-called "deficit models," but is more aptly described as an **antidote** to deficit models. Students will be shown that they are *not alone*, rather than be shown that they are the only one who struggles. Digital tools have already helped our students connect and grow, despite the quarantines induced by COVID-19.

The COVID-19 pandemic forced our department to shift to digital educational platforms. Normally, our introductory STEM curricula is centered on both laboratory and lecture courses. In 100-level physics courses, we have merged lecture and lab at the introductory level, using concepts from workshop physics models and peer-instruction (PI) [1]. Peer-instruction models have the students play an active role in teaching each other, and the content is transmitted through the instructor *and peers,* leading to better learning outcomes. Components of our courses remain online and asynchronous going forward. One example is the Pivot Interactives lab platform, in which students can complete lab activities remotely in a way that fits into their schedule [13]. Thus, there is precedent for the further use of digital tools to boost student success in STEM.

One final idea for the proposed digital tool is derived from a novel entitled The Diamond Age, by Neal Stephenson. In the book, a digital tool called *The Primer* falls into the hands of a young orphan named Nell. Nell engages with the tool, which teaches her mathematics, design principles, physics, and leadership skill. The key to her development is that The Primer *adapts* to her educational needs in real time, and provides a narrative for her growth in terms of creating a land for her fellow orphans. The MathBot project [10] already has achieved a conversational model similar to that of The Primer. To these already-successful models, we would add the narrative through digital storytelling of The Primer by incorporating digital-storytelling and graphic design from Whittier College. As the story progresses, students would be prompted to solve progressively more challenging problems in order to build strength. Duolingo combines digital storytelling and machine-learning in this way. Thus, the project would have a liberal arts component, and a software design component. In the coming sections, we describe the software design and digital storytelling of the proposed tool. We also provide an assessment plan with more detail regarding important objectives and milestones.

**Two essential actions would be performed by the software as the student progresses.** First, exercise and demographic data such as response rate and time, correct percentage, and student race and gender, would be recorded anonymously for further analysis. Machine-learning algorithms (see below) would be run on trial data to help instructors understand student learning patterns. Insights derived could be taken into account in our courses. If we find, for example, that students of color regularly struggle with vector addition and momentum conservation (most likely due to non-exposure to these topics in high-school or at Whittier) then providing more in-class practice in those topics should *boost* equity, rather than exacerbate it. The second action performed by the code would be to establish the pace and intensity of the course. If we find that historically marginalized students demonstrate strength in certain topics, relatively less in-class practice should be spent on those topics. The net gain for marginalized students is that they are exposed to *more content* than they would experienced without the data-driven model. Thus, the software facilitates an adaptable course that maximizes the learning of people who have traditionally been marginalized.

**Whenever one encounters *digital storytelling* or *narrative* anywhere in this proposal, do not forget that it will not be and should not be a physics instructor creating these stories and themes.** Rather, we plan to recruit Whittier Scholars Program students, digital design students, and staff members from Wardman Library to drive creation in this area. There are three reasons it makes sense to do the project this way. First, the Digital Liberal Arts area already has the experience to help students tell their own stories. As stated above, we regularly invite staff members such as Sonia Chaidez from Digital Liberal Arts to train students in introductory physics courses how to create a digital story about their science projects (usually with WeVideo). Having gained experience with tools like WeVideo, we now have access to a plethora of institutional wisdom in digital storytelling. Second, undergraduates from diverse backgrounds will be recruited to create the digital storytelling piece, so the narrative themes should be recognizable and dignity-affirming to the user, unlike a sterile traditional textbook. Third, the format will move the data collection and analysis anonymously to the back end, so that the students are anonymously helping their instructors learn about them.

**Current physics students at Whittier College already generate data that goes unused, and our students of color and female students are not yet benefiting from its analysis.** There are many examples in EDM literature that demonstrate how clustering and classification algorithms are used in STEM education. One example of clustering algorithms was [14], in which researchers identified patterns in self-regulated learning (SRL) in a large asynchronous online statistics course. Another example was [15], in which student problem-solving clusters emerged from data generated in a physics MOOC (massive open online course). On occasion, EDM researchers develop educational protocols and tools based on the results. Probably the most applicable example to our introductory physics courses is the MathBot [10].

In introductory physics courses, we have been using the Force and Motion Concept Evaluation (FMCE) in introductory physics courses [2]. We use the FMCE data primarily to evaluate our progress as instructors. However, we do not *continue* to record data that *re-informs* our picture of our students, nor do we systematically tailor content to the students as they evolve. In addition, we would like to make our proposed tool cognizant of student demographic data. To strive to be as equitable as possible in our 100-level physics courses, we should at least be using the data that students of color and young women generate. No matter the background of the student, the adaptability the machine-learning tools in EDM literature should be deployed to form an equitable foundation of skills for Whittier Poets.

**Equity and inclusion are core values of Whittier College.** The idea that each student could be given free access to a digital tool that helps train them in advance of and during introductory physics courses fosters equity and inclusion at our institution. It is our hope that we will affirm the dignity of our physics students and customize their course content by creating this tool. Seventy percent of our student body identify as people of color, which is not true of Whittier faculty. By allowing students to drive the creation of the digital-storytelling, we will infuse it with narrative themes and imagery that align with the identities of the very people we instruct.

**The ideas behind this project are in alignment with our Racial Justice and Equity Action Plan.** For example, part of the plan calls for increased data collection and analysis with a focus on equity, inclusion, and retention of Black students. We should strive to collect educational data so that their educational experience may be improved. Another portion of the plan calls for an associate dean to "lead efforts in evaluating, modifying, and implementing policy and practices and augmenting faculty development." Bringing this tool to the instructional landscape will demonstrate exactly how faculty can evolve their teaching practices to better serve our students.

**Project Timeline and Project Assessment**

- *Team recruitment and planning stages*
  - Because we propose designing an app for Android OS, it would be helpful to recruit a computer science student involved in the Whittier Scholars Program. Prof. Hanson of the Dept. of Physics and Astronomy advises at least one such student per year, so this should not be difficult. Other programming expertise can come from projects created via PHYS396: Physics Research for Credit.
  - We need to recruit motivated Whittier Scholars Program (WSP) and digital design students interested in creating digital artwork and storytelling themes for the application. We had anticipated being able to reward these students financially. Those in charge of the POET internship program have indicated this is a strong proposal for such a POET intern, however, funding would have to arrive in the next academic year because the application window is closed. This should not hinder progress, however, because the nature of this project is such that we must create a skeleton of software first before infusing it with digital narratives.
  - We estimate a timeline of 1 month for software design recruitment
- *Character creation, story development, and STEM content generation*
  - We assume that the digital storytelling side of this project will undergo refinement such that there is a workable story and set of digital designs that can be implemented as the visual content of the application. The portfolio should be broad, to account for students moving through it via multiple pathways. We estimate two semesters to complete this, starting in Fall 2022.
  - On the coding and analysis side, we must have the minimum ability to collect data from a device running the application in a central location, and separately run machine-learning algorithms on it. We estimate two semesters in parallel with the digital storytelling side for this work.

    - Optimally, we should determine how to execute machine-learning algorithms tools within the application.  Ideally, we'd like to have this integrated at the end of the second semester.
- *Initial machine-learning studies*
    - In the second and third semesters of this work, we will run machine-learning studies on the data generated by volunteer users.
    - We will investigate the usage of cited EDM algorithms, but we will make time for more detailed and broad studies of how this data is processed.  The analysis of this data could form the backbone of a Whittier Scholars Program major design.
    - In the final stages, we must demonstrate that the application can change based on the user, in the same sense as DuoLingo.
    - We estimate this work taking place during the third semester of the project.
- *Expanded testing on larger sets of student volunteers*
    - This would mark a useful stopping point for this work.
    - If we succeed up to this phase, the moment would be ripe to apply for an external grant focused on scaling up the processes to incorporate more introductory STEM courses.

**Financial Compensation**

Given that external sources such as POET internships will be sought for student compensation, there is no financial component to that part of the project.  However, Prof. Hanson will be writing software for this project, so we do request the maximum of $500.00 from the proposal call.

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