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Transformation of graduate school research projects to community college internship projects with translation to high school Science Talent Search projects

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Transformation of graduate school research projects to community college internship projects with translation to high school Regeneron Science Talent Search projects

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Abstract

The 2015 Gen-Z survey by Barnes & Noble Colleges showed that only about 12% students can learn in the tradition lecture setting. One effective solution in the teaching of Gen-Z students would be the availability of hands-on project learning in an internship setting, rather than as part of a traditional course. The transformation of graduate school research projects such as Synchrotron-based X-ray spectroscopy, muon coincident events generated by cosmic ray bombardments, visualization of supercomputer simulations, etc. have been transformed to a level suitable for community college level internship projects with a translational extension for Science Talent Search projects suitable for high school students. The transformation and translation principles have been formulated using episodic future thinking and semantic memory learning models, with a parallelism to bi-literate acquisition in the learning of languages. The assessment of the resulting transformed and translated projects is discussed.

Keywords

Research transformation, school project translation, Regeneron Science Talent Search, episodic future thinking.

Introduction

The 2015 Gen-Z survey by Barnes & Noble Colleges showed that only about 12% students can learn in the tradition lecture setting[1]. The disconnection of lecture style teaching from student learning can become a national issue if the trend continues. The college level physics courses in mechanics and electromagnetism in our community college usually have more than 90% engineering and technology students. One effective solution in the teaching of Gen-Z students would be the availability of hands-on project learning in an internship setting, rather than as part of a traditional course. On the one hand, the implementation of hands-on projects could focus on using the lab experiments as the basis, and then expanding the lab experiments to hands-on projects using computer data collection and computation software such as Matlab, Python, etc. On the other hand the transformation of graduate school research projects such as Synchrotron-based X-ray spectroscopy, muon coincident events generated by cosmic ray bombardments, visualization of supercomputer simulations, etc. to a level suitable for community college level internship projects is also doable, with a translational extension for Science Talent Search projects suitable for high school students in a college outreach program. From the perspective of a graduate student, the transformation from graduate school level to community college level includes the reading of poplar science magazines or web reviews at the high school physics level rather than the reading of the original publications, the procedural duplication of the lab experiments rather than the innovation of a new design and/or construction, and the analysis of the collected data in simple platforms like Microsoft Excel-VBA, Matlab, or elementary Python.

From time to time, we have been asked to help high school students to participate in the Regeneron Science Talent Search competition[2]. The translation of community college projects to high school projects could follow the principle of bi-literate translation between two languages. There is a distinction between basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP) as the schooling would shape language in the context of academic subjects[3]. A community college project would be translated to a high school project academically.

Over 95% calculus physics students in our community college have been engineering majors. It would be ideal when the transformation can help engineering students to develop an engineering mindset in a community college. The advances in learning theory can help community college faculty mentors to design projects that would encourage engineering mindset development. Innovation or creativity is of paramount importance in the development of an engineering mindset. Recent fMRI data showed that creativity is supported by three brain networks which are normally not activated simultaneously[4-6]. The three orthogonal-like brain networks are the default network for mind wandering with episodic memory, executive control network for task execution, and salience network for deciding when to switch between default and executive networks [7]. Another recent fMRI finding showed that physics learning would involve episodic memory and be a good platform to study student learning effectiveness due to the fact that physics contains daily life experiential examples and also is based on laws[8, 9]. Recent studies showed genetic signatures in education attainment and purpose of life searching [10-11], although another previous education research report showed that the studied boys and girls up to 8 years old exhibited similar numerosity perception [12]. From the perspective of a faculty mentor, the transformation of a graduate level project to a college internship project could include components that would activate the default, executive and salience networks. The components could include episodic memory engagement, solving tasks in data processing and detector building, making statistical inferences with Bayesian decisions, etc. The translation to a high school competition project could use the cognitive academic language proficiency (CALP) perspective in bi-literacy instruction to support the Regeneron applicant's purpose of life aspiration with the knowledge of a college academic subject. A very important component in experiential learning is the training for episodic future thinking. Neuroscience research results showed that those having episodic future thinking would do much better in salary earnings than those who cannot accept delay gratification[13]. A recent research report on free-will showed that the agency attribute, (sense of responsibility in one's action) would be associated with the brain precuneus structure, which is also used for episodic memory and exhibited evolutionary selection[14]. The graduate school is an institution with delayed gratification and it is important for community college students to appreciate the transformations and consider graduate school education.

Implementation

Student research project has been recognized as high impact strategy for student learning. Aristotle wrote about learning through doing and the modern theory of experiential learning has been pioneered by Kolb and further developed by others. The four basic elements in the Kolb's theory are Active Involvement, Specific Experience, Reflective Learning, and Conceptualization with Application. Some Learning Centers have summarized the essential issues and posted their summaries in the open literature[15-17]. The transformation of a graduate level project to a community college project could follow the theory of experiential learning. We have implemented the High Road/Low Road physics analysis as a teaching analogy for the Synchrotron-based X-ray Absorption Spectroscopy student project[18,19]. The physics of High Road Low Road is about the conversion of potential energy to kinetic energy in time such that the object taking the low road would be more power-efficient and arrive first when compared to the object taking the high object. The Earth as an object would lose more angular momentum from interacting with the low road object when compared to the interaction with the high road object. An object M1 as illustrated in Figure 1 would exchange energy with the sliding object, just like a ball thrown toward an incoming car would gain energy upon re-bounce. In other words, the exchange of energy is a resonance condition between the sliding object and M1.

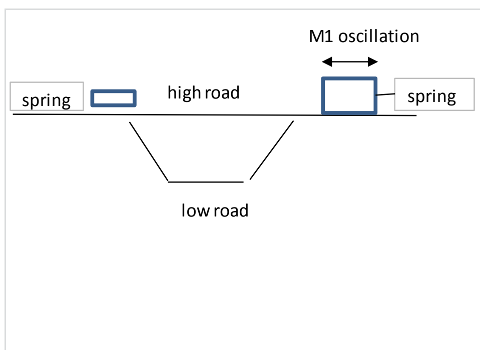

Figure 1: A schematic view of the M1 oscillation in the high road/low road example.

Note that higher harmonics could also exchange energy such that the third harmonic frequency would allow exchange energy in every third cycle (Figure 2).

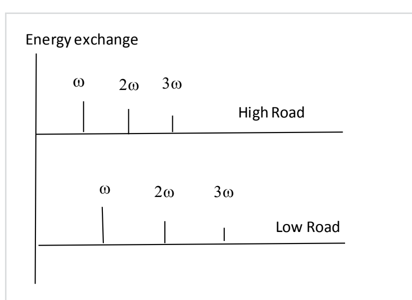

Figure 2: A schematic view of energy exchange as a function of frequency values.

When the situation is modified by a potential barrier as illustrated in Figure 3, it is obvious that the oscillation energy would be the remaining energy after climbing the potential barrier.

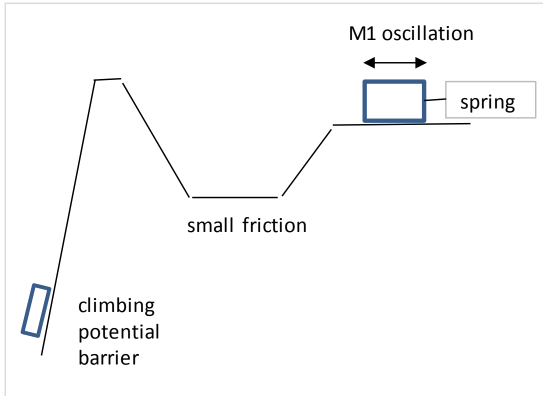

Figure 3: A schematic view of a sliding object overcoming a potential barrier.

A typical Synchrotron-based X-ray Absorption data plot has a similar feature where the remaining energy given to the released photoelectron upon X-ray absorption would show resonance when partially confined by the potential walls of the neighboring atomic potentials, shown in Figure 4.

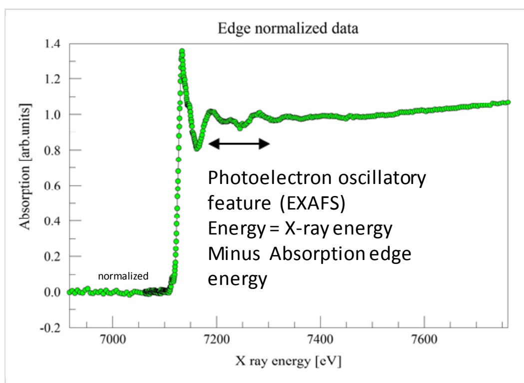

Figure 4: An illustration of Extended X-ray absorption Fine Structure data and its analysis.

Although the quantum resonance for the superposition of the reflected electron wave and the out-going electron wave has no analogy in a Physics One course, Physics Two course offers a working analogy. The vibrating string experiment on measuring the wave velocity (proportional to string tension divided by mass per unit length) together with the relationship between frequency and wavelength would offer a working analogy in which the allowed wavelength would depend on the given confinement size. The formula fn = n/2L * √(tension per unit length) for the n-mode excitation clearly shows that the wave resonance condition depends on L, the string length or confinement size. The transformation of a graduate project to a community college project could be built using the principle of experiential learning.

Queensborough Community College is a member of the Fermi Lab QuarkNet Project[20]. We have received QuarkNet equipment such as scintillation slabs, electronic equipment, etc. to enable us to build muon detectors to characterize cosmic ray events. The graduate student level work would focus on cosmic ray propagation simulations under various conditions. The community college students would focus on the standard counting electronics in the building of the detectors for muons which are generated by pion decays during the cosmic ray bombardments on our atmosphere. When gesturing has been reported as an important tool in physics education, the gestures involved in the teaching of equipment building in a lab are at least a few times more frequent than the gestures used in a classroom[21]. Whether the gesturing response capability is a compensation for human selective cognitive listening is an interesting conjecture[22]. The visualization of supercomputer simulations such as those simulations done by the IllustrisTNG Cosmology Research Group at the graduate level can be transformed to community college internship projects with a focus on the statistical analysis of the simulation results[23]. Other computer simulations include the temperature correction for the muon flux with numerical integration. In these cases, the experiential learning would be in the areas of computer signal processing and data visualization with direct semantic processing improvement, which would be an important factor in career choices such as machine learning using Bayesian-like decisions.

The translation to high school projects would retain the cognitive academic aspect. For example the synchrotron project could be translated to a public health issue in terms of arsenic elemental concentration with some basic academic knowledge on the interacting electrons. The muon detection college project could be translated to an application in tomography while keeping the same engineering designs. The high school muon project could work with high signal to ratio (S/N) cases while the low S/N cases would be tackled by college students with college level academic subjects including engineering and technology. Faculty members usually participate with the goal of delivering inspiration to high school students in terms of design concepts and engineering mindset development which are already implemented in college student projects. On the one hand, the high school students applying for Regeneron Science Talent Search competition usually show aspiration, perhaps with some misconceptions. On the other hand, our community college students would need to see that their projects are transformed from graduate school level so as to recognize inspirations from faculty mentors with the purpose of encouraging them to continue to graduate schools.

A community college student internship project can start with an introductory to research college course. For example, our Department had such a course in Spring Semester 2018. The 90-hour course has the learning objectives and outcomes with a regular formative and/or summative assessment structures. A faculty mentor participation in the Regeneron Science Talent Search is a volunteering service to the neighborhood community and the participation may not involve a course listed in a college catalog. The clear steps of transformation to a college level internship project and then a translation to a high school level competition project would facilitate assessment in the volunteering service.

Assessment Results

Some of the high school student assessments on detector electronics and computer visualization projects have been reported by us in an open access paper available on the SPIE Digital Library last month[24]. In this paper the assessments related to episodic memory in terms of diagrammatic information (or graphical abstract) and semantic memory in terms of making inferences are addressed in Table 1, developed by the department for faculty mentors to assess the students. The general education objective of using analytical reasoning skills to make inference about physical phenomena for each student has been assessed with deliverable tasks.

Table 1: General Education assessment rubric

Deliverable	Highly competent	Competent	Needs Improvement
Wrote an inference using the data	Wrote a clear inference using the data & graphs	Wrote one questionable concept	Contained two or more unclear concepts
Made an informed judgment	Made a correct evaluation in support of a judgment	Made a weak evaluation	Made a judgment without evaluation
Made a PowerPoint with effective color diagrams	Provided color diagrams were clear and correct	Provided color diagrams had one or two misatkes	Contained three or more mistakes in the diagrams
Communicated effectively with clicker tools	Provided a clear oral presentation of the PowerPoint and showed an effective use of the color diagrams	Provided an presentationm with one or two mustakes but the meaning was mosty intact	Presentaion contained three or more mistakes

An assessment rubric with student deliverables for research project outcomes had been conducted, with three faculty mentors rating a project. Deliverable-1 contained the identification of key concepts, laws and tools relevant to the phenomenon being investigated. Deliverable-2 contained the showing of familiarity with standard statistical quantities used in science research. Deliverable-3 contained an explanation of the research project using an analogous model in elementary physics at the junior high school level. Deliverable-4 contained the generation of a new hypothesis for a future project, a measure of the success of the faculty mentoring goal in terms of the delivery of inspiration. In the Summer Semester of 2018, all the 8 community college students reached competent and highly competent levels, while one of the high school students reached highly competent level (25% in each of the four deliverables).

Conclusions

It is important to have future studies that include assessments on the tasks designed for the development of an engineering mindset, especially in relationship to episodic future thinking which was found to link to personal semantic memory [25,26].

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