Improving learning motivation through physics lessons that include relationships between science technology and society for engineering and technology students

George Tremberger, Vazgen Shekoyan, Sunil Dehipawala, Rex Taibu, David Lieberman, and Tak Cheung
CUNY Queensborough Community College Physics Department

Abstract
It was reported last year that learning motivation could be traceable to a genetic origin and that STEM attrition among college students when compared with other majors such as business is a considerably large 48%. Faced with an open admission policy in a community college setting, an attempt to improve retention was implemented with the hypothesis that learning motivation not properly developed in high school years could be triggered by requiring students to learn about the relationships between science, technology and society and that the knowledge learned is measurable in terms of student deliverables. Progress in physics requires the material advancement in lab equipment such as springs, capacitors, etc., while society's transformation has in large part rested on the corresponding elements such as the trebuchet, the steam engine, the cell phone, etc. Examples of the relationships used in physics teaching are discussed in this report. Physics advances relevant to the historical events are supplemented with parallel examples in art history and British literature for easy visualization by the student to promote affective learning in a comprehensive curriculum. Important emerging technologies, such as EEG and muon radiography using cosmic rays for home land security applications are among the topics discussed. The learning assessment rubric of Highly Competent, Competent, and Needs Improvement versus Participant Deliverables was used. An improvement was observed in the grades of discussion sections of lab reports and the written interpretation of numerical calculations. The sustainability of such triggered learning motivation through the teaching of perspectives in science, technology and society could be enhanced if an independent college course in Science, Technology and Society has a STEM course as pre-requisite.

I. Introduction

An Intelligence test result analysis had identified test motivation as an important factor in low stake intelligence testing condition and also as a strong predictor for test scores in college \(^1\). Recently personal qualities such as self-control, grit and growth mindset has been studied in relationship to the more explicit cognitive skills such as intelligence and knowledge, and the report recommended more measurements on personal qualities for education purposes \(^3\). It was reported last year that learning motivation could be traceable to a genetic origin \(^4\), and that STEM attrition among college students when compared with other majors such as business is a considerably large 48% \(^5\). Faced with an open admission policy in a community college setting,
an attempt to improve retention was implemented with the hypothesis that learning motivation not properly developed in high school years could be triggered by requiring students to learn about the relationships between science, technology and society and that the knowledge learned is measurable in terms of student deliverables. A 2016 report found that peer excellence could be a risk factor for discouragement and quitting, and a professor promoting learning motivation would need to be prepared to alleviate the presence of peer excellence pressure in the classroom.

II. Technology and Physics

Progress in physics requires the material advancement in lab equipment such as springs, capacitors, etc., while society's transformation has in large part rested on the corresponding devices such as the trebuchet, the steam engine, the cell phone, etc. The trebuchet based on the principle of energy conservation was able to destroy a castle and its related political power. The steam engine based on the understanding of thermodynamics played an important component in the industrial revolution. The cell phone impact on communication which drives the current information revolution would not require further description to any student. Clean energy such as Wind Power Technology can be discussed in physics class in terms of the basic equations such as flow rate and power in fluid mechanics. Knowledge consists of fact, information and skill, according to the Oxford Dictionary. The skill component in the knowledge learning of the above devices can be assessed by asking physics questions using the appropriate numerical values in the devices. For example, the experimental values of a field-tested trebuchet could be used in a lecture setting in terms of angular momentum, velocity, and acceleration. The Watt's Famous Experiment of the Separate Condenser description is available online with the appropriate experimental values suitable for thermodynamics calculation in a lecture setting. Wind power examples with realistic numerical values can be found online as well.

III. Society, Technology, and Physics

Society plays an active role in pushing technology and science. Historical event discussion such as the longbow deployment in the English-French 100-year Conflict is a well-known example where technology determined the outcome, although the physics of the longbow technology was finally put forward by Newton 200 years later. The technology of the atomic bomb and the physics of the Manhattan Project is another example that society demanded physics application and created nuclear technology. However, we found that the learning motivation of the students have not improved much with this strategy of showing how physics is related to historical events in terms of feasibility and the consistency with all known physical laws. Therefore the physics advances relevant to the historical events are supplemented with parallel examples in art history and British literature for easy visualization by the students to promote learning in a
comprehensive curriculum. The story of Einstein’s formulation of stimulated emission to CD music has been pioneered by Sir Michael Berry in his popular talk on “How quantum physics democratized music”\textsuperscript{12}. Our CUNY TV has a public broadcasting of a literature series on the British Literature. The theme “As English spreads across the globe, becoming the language of the Internet, understanding the extraordinary body of British literature has become ever more vital in the 21st century”\textsuperscript{13}. Swift's critique of science at the time in his “Gulliver's Travels” was credited by Bloom in his 1990 review\textsuperscript{14}. These added teaching activities are designed with the hypothesis that cognitive learning can be improved with affective learning\textsuperscript{15,16,17}, which recently was found to be originated from the brain amygdala region\textsuperscript{18}.

With the advances of internet technology, social media like YouTube videos regularly depict interesting science applications. For example, the water rugby launching based on displaced fluid physics that would result in a higher launching speed and the saving of a free falling person when tied to a rotating object via angular momentum concept are good examples for fact and computational skill training in the learning of knowledge\textsuperscript{19,20}. Social media hosting science videos is a rapidly growing phenomenon. Youtube can provide a low budget maintenance platform from the viewpoint of a professor author, independent of a university budget.

Students usually would focus on what are being graded and they study to the graded policy. If the grading has little weight on writing an explanation, the students would simply ignore the verbal thinking aspect and just apply algorithm learning to get to the numerical answers asked in physics questions. In a typical example where a block on a ramp is connected to a vertically hanging block via a cord, the acceleration and tension can be calculated with algorithm learning. However, in a learning assessment in terms of verbal thoughts and writing skill, most of the students would fail to show in their writing that the acceleration answer must be less than 9.8 m/s/s; and that the tension is the force that pulls up the block on the ramp and the same tension prevents the vertically hanging block from free falling by acting as a burden.

Learning with emotion in the affective domain that connects physics with technology and society has been utilized. The obvious examples of ladder safety in relationship to the inclined angle and ground friction, house fire eruption when too many heaters, tire skidding, etc. are insurance policy related issues. In the case of house fire caused by electricity overload, a Judge would rule that it is not the design engineering fault when the heater device met all government safety rules, but a violation of Ohm’s Law in physics. Important emerging technologies, such as electroencephalography EEG used to study the science of learning and muon radiography using cosmic rays for home land security applications are also among the topics discussed. A physics class on Electricity and Magnetism has a good platform to include EEG topics while a physics class in modern physics provides ample opportunities to include muon decay when teaching relativistic correction and scattering cross section. The sustainability of such triggered learning motivation through the teaching of perspectives in science, technology and society could be
enhanced if an independent college course in Science, Technology and Society has a STEM course as pre-requisite.

The learning assessment rubric of Highly Competent, Competent, and Needs Improvement versus Participant Deliverables was used. An improvement was observed in the grades of discussion sections of lab reports and the written interpretation of numerical calculations. The student performance has been assessed as satisfactory (score above 75% using highly competent = 1, competent = 0.8 and needs improvement = 0.6). The rubric guideline is displayed in Table 1.
<table>
<thead>
<tr>
<th>Participant Deliverable</th>
<th>Highly Competent</th>
<th>Competent</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture Objective Question Physics &amp; Tech (20%)</td>
<td>Summarized the physical laws clearly and concisely with graphs and formulas in relationship to a technology application</td>
<td>Summarized the physical laws clearly with formulas but without graphical expression</td>
<td>Summarized the physical laws with wrong calculations</td>
</tr>
<tr>
<td>Written Interpretation of Lecture Numerical Info Phys-Tech-Soc (20%)</td>
<td>Provided clear explanation of the relationship of physics and technology to society on the lecture numerical information; and sentences with enthusiasm indicative of an affective learner</td>
<td>Provided clear explanation of the relationship of physics and technology to society on the lecture numerical information; but no indication of an affective learner</td>
<td>Provided unclear written explanation</td>
</tr>
<tr>
<td>Numerical Interpretation of Social Media Video Info Phys-Tech-Soc (20%)</td>
<td>Summarized the physical laws clearly and concisely with graphs and formulas in relationship to a technology application displayed in a social media</td>
<td>Summarized the physical laws clearly with formulas in relationship to a technology application displayed in a social media but no indication of an affective learner</td>
<td>Summarized the physical laws with wrong calculations</td>
</tr>
<tr>
<td>Written Interpretation of Social Media Video Info Phys-Tech-Soc (20%)</td>
<td>Provided clear explanation of the relationship of physics to a technology application displayed in a social media; and sentences with enthusiasm indicative of an affective learner</td>
<td>Provided clear explanation of the relationship of physics to a technology application displayed in a social media; but no indication of an affective learner</td>
<td>Provided unclear written explanation</td>
</tr>
<tr>
<td>Lab Report Discussion Phys-Tech (20%)</td>
<td>Provided clear explanation of the relationship of physics and technology on the lab result; and sentences with enthusiasm indicative of an affective learner</td>
<td>Provided clear explanation of the relationship of physics and technology on the lab result; but no indication of an affective learner</td>
<td>Provided unclear written sentences</td>
</tr>
</tbody>
</table>

Table 1: Physics, Technology, and Society Learning Assessment Rubric. The participants are students. Scoring could be performed when assigning Highly Competent = 1, Competent = 0.8 and Needs Improvement = 0.6.
IV. Discussion

A book was published on Dev 2015 that creativity carries two different neural networks. But before a book can be written, there were science details being published first. It was found that the promotion of effective balance between external attention and constructive internal reflection is the key to creative with critical thinking. There is no doubt that a musician would need to learn in the affective and psychomotor domains. A recent research study on musician creativity show that the neural mechanisms involved in their creativity can be automated with training, and experienced improvisers showed greater functional connectivity. Results of affective learning in self recollection have been reviewed recently. The verbal thinking part that is involved in the teaching of physics, technology and society is an important element to activate the affective learning.

The affective learning implementation was found to be more effective with explanation to the students at their level. For example, a Scientific America article said that “In a recent large review, Rex Jung and colleagues provide a "first approximation" regarding how creative cognition might map on to the human brain. Their review suggests that when you want to loosen your associations, allow your mind to roam free, imagine new possibilities, and silence the inner critic, it's good to reduce activation of the Executive Attention Network (a bit, but not completely) and increase activation of the Imagination and Salience Networks. Indeed, recent research on jazz musicians and rappers engaging in creative improvisation suggests that's precisely what is happening in the brain while in a flow state. However, sometimes it's important to bring the Executive Attention Network back online, and critically evaluate and implement your creative ideas.” The recently posted quick recipe of using 4 steps to increase creativity is also at the student reading level. When students understands the mystery of creativity with neuroscience results and the connection to affective learning, the inclusion of the relationships of physics, technology and society has been found to be welcomed by students.

The affective learning would reinforce cognitive learning of the course objectives, support entrepreneurial- minded learning as advocated by the KEEN Foundation, reduce procrastination as reflected in their submission promptness, and improve academic creativity as reflected in the writing assignments. The design of a smart heater device that can detect line voltage fluctuation due to another heater on-switch flipping and then would shut off to avoid a house fire is a service to society in the context of entrepreneurial- minded learning. The entrepreneurial- minded creativity of having new designs for the needs of society could be an effective tool to reduce the dropout rate but longitudinal assessment data beyond the scope of this project would be needed for a definite proof.
The physics-technology-society pedagogy would promote students to understand society with a new perspective and would increase relatedness and awareness. Peer learning pedagogy would promote sharing and altruistic behavioral. Recent fMRI scan had confirmed different wiring in the altruistic brain. The question of whether physics-technology-society pedagogy learning assessment could be done with fMRI scan is an interesting conjecture.

V. Conclusions

The pedagogy of requiring students to learn about the relationships between science, technology and society has been implemented. The knowledge gained is measurable in terms of student deliverables with a learning assessment rubric. An improvement was observed in the grades of discussion sections of lab reports and the written interpretation of numerical calculations. The creativity of having new designs for the needs of society could be an effective tool to reduce the dropout rate. Future studies could include a longitudinal data collection and analysis for the purpose of understanding the current STEM dropout rate and its prevention.

VI. Acknowledgements

Partial supports from several CUNY grants are gratefully acknowledged. We thank Alexei Kisselev for laboratory support. We thank the anonymous reviewers for their suggestions.

VII. Bibliography

Journal of Technology and Science Education. Vol 5(1), 2015, pp 41
http://web.mit.edu/windenergy/windweek/Presentations/Wind%20Energy%20101.pdf
8. Anton Zack, 2013, Trebuchet and Projectile Dynamics
http://aeweb.tamu.edu/aero211/Presentations/AntonZack.pdf
9. Carl Lira 2015 Brief History of the Steam Engine, Summary by Carl Lira
http://www.egr.msu.edu/~lira/supp/steam/
10. Carl Lira 2015 Watt's Famous Experiment of the Separate Condenser, Summary by
http://www.egr.msu.edu/~lira/supp/wattexp.htm
http://chethermo.net/students
http://zebu.uoregon.edu/2004/hc441/lec09.html
http://pages.uoregon.edu/stamm/phys162w2008/
(Published on YouTube Aug 3, 2015)
https://www.youtube.com/watch?v=UPrjIfQ5AQA
http://www.cuny.tv/show/greatauthorsofthebritishisles/PR2003389
Great Authors of the British Isles March 2013
http://www.ambrosevideo.com/items.cfm?id=1417&category_id=3
http://epltt.coe.uga.edu/index.php?title=Teaching_and_Learning_in_Affective_Domain
16. NAGT Workshop (2007) Student Motivations and Attitudes: The Role of the Affective Domain in Geoscience Learning. What is the Affective Domain anyway?
http://serc.carleton.edu/NAGTWorkshops/affective/intro.html
17. Thomas Koballa, 2007 Framework for the Affective Domain in Science Education
http://serc.carleton.edu/NAGTWorkshops/affective/framework.html
https://www.youtube.com/watch?v=kVSu5FWTX1I
20. YouTube January 2016 Risks life to prove physical law by NRK Viten https://www.youtube.com/watch?v=5ZnKIPfhlAQ
Connecting to create: expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas.
27. Scott Barry Kaufman 2016 Feb, 4 Ways to Hack Your Inner Creativity
http://scottbarrykaufman.com/article/4-ways-to-hack-your-inner-creativity/
28. KEEN Video Entrepreneurial vs. Traditional Engineering (2013)
http://keennetwork.org/video/item/67-entrepreneurial-vs-traditional-engineering
Vol. 351, Issue 6277, pp. 1028-1029
http://science.sciencemag.org/content/351/6277/1028.full