Service Learning and Humanitarian Application Pedagogy in Community College Pre- engineering Physics Class

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Abstract
Queensborough Community College in New York City has an active Service Learning Pedagogy across various disciplines including physics; and we have taken the service learning opportunity to introduce our physics class students to humanitarian application as well. Collaboration between faculty and community partner in designing a project based on the partner's specific goals and needs is an important aspect. The pedagogy in teaching service learning with the New York Public Interest Research Group (NYPIRG) as a community client is discussed in this report. NYPIRG conducts student meetings and a quantitative report would promote conversation with substantial evidence in social learning and enhance informal STEM learning outside of classroom environment. Besides the regular learning goals related course technical objectives, the additional learning goals of enhancing social learning and communication skill by supporting NYPIRG with physics modeling results have generated the following objectives. The student learning objectives include the understandings of voter pattern analysis via the Ising Model, pedestrian dynamics via the Brownian motion model, and wealth dynamics via the Fokker Planck equation. The introduction of a client's request in terms of pictures and graphics are essential to keep the student cognitive load within his/her capability. The related numerical tasks with Excel software technology have been observed to reduce the anxiety of physics concepts encountered by community college pre- engineering physics students. A humanitarian application in the area of voice pattern analysis in the context of victim-offender mediation, a topic in computational social justice, is also discussed.

I. Introduction

Queensborough Community College in New York City has an active Service Learning Pedagogy across various disciplines including physics; and we have taken the service learning opportunity to introduce our physics class students to humanitarian application as well. Queensborough Community College introduced servicing learning via the quotation from US Government Learn and Serve America [1] "Service-Learning is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities."

Collaboration between faculty and community partner in designing a project based on the partner's specific goals and needs is an important aspect. The pedagogy in teaching service learning with the New York Public Interest Research Group (NYPIRG) as a community client is discussed in this report. NYPIRG is an organization with concerns on social issues. Their website has a clear description of its mission. The New York State's largest student-directed research and advocacy organization is NYPIRG [2]. The current focuses are on environmental protection, consumer rights, higher education, government reform, voter registration, mass transit and public health. NYPIRG is a nonpartisan and not-for-profit group with the aim of training students and other New Yorkers to be advocates.

NYPIRG conducts student meetings and student generated quantitative reports would promote conversations with substantial evidence in social learning and enhance informal STEM (Science Technology Engineering Mathematics) learning outside of classroom environment. NYPIRG aims to train students to be better advocates equipped with knowledge beyond the quotation of summary statistical information. The student learning goals of enhancing social learning and communication skill by supporting NYPIRG with physics modeling results have generated the following objectives. The student learning objectives include the understandings of voter pattern analysis via the Ising Model, pedestrian dynamics via the Brownian motion model, and wealth dynamics via the Fokker Planck equation. The student learning objectives in relationships to the general education objectives and course objectives are discussed.

A humanitarian application in the area of voice pattern analysis in the context of victim-offender mediation, under the general topic of computational social justice, is also discussed in this report. The application has served as a connection for a community college student interested in humanitarian engineering courses after transferring to a senior college.

II. Implementation

Service learning with connection to a social science subject is a clear implementation methodology to connect learning goals to the needs of a community. The role of physics modeling that impacted social sciences the most has been generally accepted as the Journal of Political Economy publication of the Black-Scholes Model in 1973 [3]. The understanding of the Black-Scholes Model is pivotal in the discipline of Options and Corporate Liabilities Pricing. The work resulted in Scholes sharing the 1997 Nobel Prize in Economics with Merton (Black, a physicist, died in 1995). Although it would be simple to include a discussion of the Black-Scholes Model as a random walk model when teaching diffusion in a physics class, our service learning partner NYPIRG is not very interested in a student report regarding the profit mechanisms of New York Wall Street and Chicago Board of Exchange CBOE. With reference to the NYPIRG concerns, three topics have been developed in physics service learning pedagogy. The topics are voter pattern, pedestrian dynamics, and wealth dynamics with analysis from a physics perspective. Although not a concern for NYPIRG, the voce pattern analysis has been implemented for students interested in computational social justice, a topic in humanitarian engineering application.

Voter Pattern

Voter pattern has been analyzed with an Ising Model physics perspective. For example a recent paper from Princeton University reported that the consistency between the Ising spin glass modeling and the observed pairwise correlations among justices' votes [4]. The Ising model (in magnetism) was introduced by Lenz in 1920 and solved in one dimension by Ising in 1925. The model is defined by placing "spin" variables σ which take on the values ± 1 on the sites of a lattice and there an interaction energy between nearest neighbor spins of $-E$ if the spins have the same value and $+E$ if the spins have opposite values [5]. The Ising Model tutorial website from University of Norte Dame has been very helpful for our students to understand the magnetization simulation results in various temperatures using the Metropolis-Hastings algorithm [6] (Notre Dame 2006). The NetLogo Simulation (NetLogo Technology 2015 [7]) and Matlab source code examples are available [6, 8].

Basically a voting model of choosing a winner out of two contesting candidates would mimic an Ising Model when voting for candidate-A is assigned a spin value of +1 and candidate-B is assigned a spin value of -1. The assumption where each voter will convince his/her neighbors that they should vote a certain way has a parallel analogy with the Ising Model in terms of the interaction magnetic energy value of -E (agreeing neighbor) or +E (disagreeing neighbor) as discussed by McCoy [5]. For each voter, the advertising campaigns and/or party loyalty influence could be studied by assigning a partiality value $h_i = -\beta$ (always voting for candidate-A) to $+\beta$ (always voting for candidate-B). Note that a partiality value of 0 would mean a swing voter that can be persuaded by neighbor to vote for candidate-A or candidate-B. In the Ising Model, this partiality is equivalent to the existence of an external magnetic field with interaction energy h_i at each site.

$$\text{Total Energy} = E \sum \sigma_i \sigma_j + \sum h_i \sigma_i$$

The σ_i would represent the spin value at site i with external magnetic field value h_i. The sum over the j sites (given i) are limited to the four next nearest neighbors in the Ising Model. The 2014 Java simulation provided by the Open Source Physics has been used successfully [9].

Besides using the various simulations, students interested in the Metropolis-Hastings algorithm details have several reading sources as well [10-12]. Other physics models, such as the noisy diffusion study using the Edwards-Wilkinson equation [13], in explaining voting behavior are not easy to implement at a community college physics class. However, a few financial engineering majors interested in the Black-Scholes Model would latch on such voting analysis methodology.

Computer science major have shown more appreciation when the Toom Cellular Automata was introduced together with the Ising Model [14-16].

Pedestrian Dynamics

The need to study pedestrian dynamics hardly requires much explanation given that our students commute in New York City. A typical web search by a student keying “pedestrian dynamics apps” would generate a few sites including a Pedestrian-dynamics dot com company selling a high school safety product in crowd management and an apps selling company UltramarineNeutrinos dot com blogging with information. In physics, the pedestrian dynamics has been studied since the 1990s, for example, the work of Helbing [17]. Computer simulation was used to solve the nonlinearly coupled Langevin equations in the model with three social forces. The social forces are the acceleration towards the desired speed, a repulsive force to keep a pedestrian at a certain distance from other pedestrians, and force to account for attractive effects such as window shopping. The Langevin equation for the velocity vector v_i has the following representation.

$$d v_i / dt = v_d e_i - v_i (t) / \tau + \text{social forces}$$

Here the first term on the right-hand side indicates the acceleration towards the desired speed v_d and an unit vector e_i for a pedestrian i. The v_i represents the velocity vector.

The class simulation reproduced the results using the Helbing input values in Reference 17. The 1995 work of Helbing et al was extended by Kwak et al in 2014 to include phase diagram analysis with the variables of social influence and average length of stay [18]. In fact the pedestrian dynamics animation, 100 pedestrians, posed on UltramarineNeutrinos dot com [19], was based on the Kwak methodology of using exponential force representation. The python script provided by UltramarineNeutrinos dot com had been checked out as well.

The pedestrian dynamics example emphasizes on the representation of an empirical force based on the observed velocity change per unit time. A recent paper discovered that the pedestrian’s projected time to a potential future collision would form a universal scaling law [20].The data showed that the interaction energy was well described by a power law with exponent 2, as shown below.

$$E (\tau) \sim (k/ \tau^2) \exp (- \tau / \tau_0)$$

Where k is a constant and τ is the time to collision, τ_0 is the largest observed value in the interaction range

The detailed explanations and video presentations, available from Applied Motion Lab University of Minnesota [21], have been quite a success in class presentation regarding student attention and enthusiasm. The American Physical Society public release also contains a description of this discovery to the general audience without college physics pre- requisite [22].

Wealth Dynamics

Even though wealth dynamics is a very important topic, but engineering students seem to be quite shy about this topic. We attribute this shyness is coming from unfamiliarity and also disinterested in the nomenclature used in economics. In the study of Economics, Pareto noticed that 80% of Italy's land was owned by 20% of the population [23]. That was the beginning of the formulation of the Pareto Index of income distribution. Pareto described the proportion of the population whose income exceeds any positive number $x \geq x_m$ as $(x_m / x)^{\alpha}$. The parameter α becomes the Pareto Index with a corresponding Pareto power law distribution of $\alpha (x_m)^{\alpha} / (x^{\alpha+1})$ for $x \geq x_m$ [24].

Another practical expression for the Pareto's Index would be $\alpha = \log(1/f) / \log((1-f)/f)$ where f represents the fraction of the population that has (1- f) of the wealth. For example $f = 0.2$, $\alpha = \log(5)/\log(4) = 1.16$. The "fair" situation where 50% of the population would have 50% of the wealth would have a Pareto's Index of infinite. The micro economics foundation of the observation made by Pareto has been studied with various asses exchange models since the 1990s. Market economics has an analogy with the kinetic theory of gas but with a different exchange mechanism [25]. Two gas molecules would collide and the energy partition would depend on momentum conservation constraint although the total energy is conserved after the collision interaction. The market economics has a different exchange mechanism which has been illustrated by the Yard-Sell Model [25].

Two individuals or agents in a society could engage in a trade with an exchange of wealth as gain and loss. The Yard-Sale Model where the exchange wealth equals to a fix small fraction of the less wealthy agent's wealth would eventually generate wealth accumulation in some agents. The closed economics system assumes that no wealth is generated or consumed. Wealth can only change hands, from one agent to another. The Yard-Sell Model assumption is reasonable because an agent could only afford a trade with gain/loss based on a small fraction of his/her own wealth, not a trade that gain/loss is based on the percentage of the wealth of the wealthy trade partner. A Yale-Sell Model computer simulation program has been provided on the internet by University of Wisconsin Physics Department [26]. Sprott started with a group of individuals with uniform wealth distribution initially. They would trade or exchange wealth with each other such that the exchange per year is a random variable between +10% and -10% for each individual. In other words, each individual would execute a random walk, some years gaining and other years losing. The final wealth distribution result after 20 years is approximately Gaussian, as expected in a diffusion process. Such diffusion process would be easily illustrated, for example, as a spreading of heat on a surface upon a heat pulse. A 1-dim heat equation solution

$$\partial f / \partial t = (1/ 2)\, \partial (\partial f)/\partial t)/ \partial t$$

With the solution f(x, t) = (1/sqrt(2*pi*t) *(exp (- x*x / 2/t)), a Gaussian pulse that would spread out spatially as time runs along, and that the maximum would decrease as the heat energy is assumed to be conserved with no heat leak to the environment [27]. The random walk simulation is consistent with the heat energy diffusion dynamics. Incidentally, the Random Walk Excel Simulation from Cornell has been found to be useful for student learning as well [28].

Sprott also showed the Yard-Sell Model simulation where the exchange is a random rate of the wealth of the poor's individual, half the time favoring the richer and half the time favoring the poorer. The resulting distribution would be a power law distribution, similar to Pareto's analysis. Our community college students were able to follow the Yard-Sell Model simulation in Excel-VBA, following the PowerBasic algorithm of Sprott 2014 [26].

One of the possible ways to avoid the end result of most wealth being controlled by a few individuals in these models would be the incorporation of a taxing mechanism in a differential equation analysis. The variable wealth (w) in the Yale-Sell Model would execute small stochastic steps $\Delta(w)$ with a probability density function P(w) such that the integration $\int$ P(w)*w*dw from zero to infinite would equal to the total wealth W.

The time evolution of P(w) obeys the Fokker Planck equation, which is basically a diffusion with an additional $\Delta(w)$ drift term with the usual diffusive term $\langle\Delta(w)\Delta(w)\rangle$ [29]

$$\partial P / \partial t = - \partial(\langle\Delta(w)\rangle P) / \partial w + \partial (\partial \langle\Delta(w)\Delta(w)\rangle\; P /2 /\partial w)/ \partial w$$

For steady state $\partial P / \partial t = 0$, the equation becomes $(\langle\Delta(w)\rangle P) = (\partial \langle\Delta(w)\Delta(w)\rangle\; P /2 /\partial w)$

A tax on wealth as redistribution would make the $\langle\Delta(w)\rangle$ contribution as a drift term since taxing is not a stochastic variable. In other words, given a wealth tax rate χ, the amount χw will be paid to tax collector with the total collected tax of χW. Redistribution to N agents would produce an expression of

$\Delta(w) = \chi W/N - \chi w$, a non-stochastic drift term.

The steady state where $\partial P / \partial t = 0$ can be solved when using the approximation that

$(\partial <\Delta(w)\Delta(w)> P/2 /\partial w) = w^2 P/2$

$\partial (w^2 P/2)/ \partial w = (\chi W/N - \chi w)P$ would admit a solution $P(w) = (\text{Constant}/ w^{2+2\chi}) \exp(-2\chi W/N/w)$ [30]

For large wealth w values, the exponential term ~ 1, and P (w) would become a power law of roughly $w^{(-2-2\chi)}$ where the Pareto's Power Law Index could be viewed as $1 + 2\chi$. Although the Constant involves a Gamma function which is beyond the level of a community college student (Reference 30, Eq-90), a comparison for different χ wealth tax rates can still be possible for the illustration of higher tax rate, broader wealth distribution width in the Yard-Sell Model. Several P(w) distributions were displaced in Figure 9 of Reference).

The fact that Congress does not tax on wealth and but on income would render the above Fokker-Planck equation inapplicable and unable to address the wealth distribution issue fully. At the state level, real estate wealth tax is expected but some local governments collect no income tax. Nonetheless, simulations using the historical US Pareto's Index data would generate various P (w) distributions with the corresponding wealth tax rates [31]. This wealth dynamics service learning project is valuable to help NYPIRG to convince student voters on the importance of wealth distribution issues.

Voice Pattern

Voice data collected during victim-offender mediation has been shown to be useful in restorative justice field [32]. The analysis system based on Fourier Transform was reported to have an accuracy of 86% in predicting the targeted ground truths. We have a Physics of Sound course for music technology students. The exercises include an analysis of singing voice time pattern using the corresponding Fourier Transform frequency spectrum. The Fast Fourier Transform FFT software has been provided by Vernier. However engineering student taking physics class usually would not encounter such experience in voice pattern analysis. The inclusion of FFT based voice pattern in physics class as an extension of light/sound diffraction has been found to be well received by the engineering students. The Vernier FFT output spectrum can be exported as an Excel file where the coefficient of variation values (standard deviation / mean) are ready computable. Whether the coefficient of variation would be accepted as evidence in court is beyond the scope of this paper. Although voice pattern analysis have not been requested by NYPIRG as a service learning topic, the inclusion would expand engineering students' horizon to the humanitarian application of FFT. There are engineering courses covering computational social justice, wealth distribution and democracy, etc. [33, 34]. The voice pattern example would be a good pre- requisite example at the community college level.

III. Discussion

Besides implementing the above projects, test questions have been designed with technical feasibility as the focus. For example a standard question of a ramp with a sliding mass, a massive pulley and a vertically hanging mass can be asked in the following manner. A parent would need to go away for a few days to hunt for food and a ramp was built for children to get water from a well without the danger of falling over the edge. The design called for a calculation such that a child would only need to control the number of blocks as the sliding mass, and be far away from the well edge. Such technical feasibility focused test questions have been found to be useful to direct the students to be aware of service learning in terms of building that ramp as a community service, and humanitarian aspect of engineering in terms of helping children. In fact the humanitarian aspect was inspired by the Dartmouth College Humanitarian Engineering opportunity where their students would work overseas in projects like bringing clean water to a community in Kenya, etc [35].

We also have the relatively obvious service learning project of asking education major students taking conceptual physics course to prepare a lesson plan in teaching elementary school students with a local elementary school as a community client. Learning outcomes include the control of syntax and mechanics as documented in the "Written Communication VALUE Rubric" report published by Association of American Colleges & Universities [36]. Partnership with NYPIRG requires more planning, in our opinion. Among the issues proposed by NYPIRG, faculty members need to design lesson delivery that will also meet the general education and course technical objectives in pedagogy assessment. The Voter Pattern via the Ising Model project merges well with magnetism, while the Pedestrian Dynamics project fits into the introductory thermodynamics component; all within a standard first year calculus physics syllabus and the learning goals related technical objectives. The Wealth Dynamics project would be suitable for a second course in thermodynamics with introduction to statistical mechanism, usually taken by our students in their last semester in a community college. About 2/3 of a class showed enthusiasm and the projects were well learned with evidence from their quantitative work. Our calculus physics class usually has over 50% recent immigrants and international students with stronger calculus skill as compared to students going through the New York City School System. This strong calculus skill group showed more appreciation on how the mathematical procedures used in physics can be applied to societal applications. The appreciation level was reflected from their questions related to their transfers to senior colleges.

The description of the US Government Learn and Serve America [1] on enriching student learning experience and teaching civil responsibilities are relatively easy to fulfill with the above projects. However the third component in the strengthening of communities is less obvious in our selected service learning projects. The additional learning goals of enhancing social learning and communication skill by supporting NYPIRG with physics modeling results have not been very successful, based on our observation. Students have shown social shyness when the presentations were outside of a physics classroom. A recent 2015 study analyzed two types of social learners[37]. Individuals who mainly attend to what the majority is doing (frequency-based learning) would perform better in social conflict test as compared to those focusing on the success that their peers achieve (success-based learning). How many of the observed shyness individuals are using success-based learning would be an interesting future pedagogy project. The Voice Pattern project did open the students' horizon but most engineering students are not interested in humanitarian application of physics. Financial engineering students are aware of the econophysics applications but they are at the 5% level among all engineering majors in our community college.

Service Learning could overlap with Group Learning [38], Wiki learning [39], Experiential Learning in Humanities & Sciences [40]. Our rubric as shown in Figure 1 was developed with reference to the Peace Corps Service Learning Rubric published in 1998 [41]. A recent 2015 report on the social contract of learning advocated the role of the teacher to change from that of a provider of information to be a shaper of knowledge, skills, and attitudes [42]. A teacher would be a catalyst, a facilitator, or a bridge. The three major characteristics of a social contract: a reciprocal relationship, establishment of mutual obligation, and an exchange of value should be incorporated into the service learning design. The reciprocal relationship and mutual obligation would be understood by a student without much explanation given a teacher- learner classroom setting. The exchange of value between the students and NYIRG, however, would be a deeper issue for a professor to explain to students. For the students, the benefits of their participation in terms of presentation experience and competency based learning would be valuable. For NYPIRG, the benefits of participation in terms of student awareness and evidence analysis would be valuable.

Participant Deliverable	High Impact	Average Impact	Minimal Impact
Meets actual community needs (15%)	Summarizes the needs of the community clearly and concisely with graphs and pictures	Summarizes the needs of the community with clear explanation without graphs and pictures	Summarizes the needs of the community approximately and adds what would be a convenient task for the participant
Helps to develop sense of caring for and about others (10 %)	Illustrates the development of caring for and about others with clear understanding of the purpose in two examples	Illustrates the development of caring for and about others with clear understanding of the purpose in one example	Illustrates the development of caring for and about others without clear understanding of the purpose
Is integrated into academic topics (10%)	Discusses the integration into academic topics and cites two specific textbook topics	Discusses the integration into academic topics and cites one textbook topic	Discusses the integration into academic topics and cites no textbook topic
Facilitates active student reflection (15%)	Summarizes her/his reflection clearly and concisely with graphs and pictures, and with increasing confidence	Summarizes her/his reflection clearly and over-indulges in graphical explanation	Summarizes her/his reflection with textbook equations only without numerical information.
Uses new Academic skill/knowledge in real world settings (50%)	Summaries the new academic skill/knowledge application with real world data	Summaries the new academic skill/knowledge application with simulated data	Summaries the new academic skill/knowledge application with data given in class

Figure 1: The Service Learning assessment rubric with the participant being the student. Scoring could be performed when assigning High Impact = 1, Average Impact = 0.8 and Minimal Impact = 0.6. The student learning has been assessed as good (> 85%) for those students showing interest.

IV. Conclusions

The inclusion of servicing learning in a pre-engineering community college setting has been investigated with three popular social issues with NYPIRG as a client for our students. As we are located in a highly populated borough of New York City together with a high percentage of immigrants that speak a total of 99 languages, the issues of voting pattern, pedestrian dynamics and wealth dynamics as lesson topics do not need much justification. The physics learning goals are reachable given the syllabi of Calculus Physics, Second Course in Thermodynamics and Modern Physics. The social contract of learning has been used to analyze the service learning goals of enhancing social learning and communication. The exchange of value between students and NYPIRG is an important aspect for professor to explain to students. Future possibilities include extension to offer service learning pedagogy to algebra based physics class students, and additional projects such as physics based traffic flow analysis.

V. Acknowledgements

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

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