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An experiential learning strategy in introductory mechanics using transferrable knowledge from daily examples and feedback inquiry in the development of an innovative mindset

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An experiential learning strategy in introductory mechanics using transferrable knowledge from daily examples and feedback inquiry in the development of an innovative mindset

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Abstract

Transferable knowledge in daily examples can be used to teach mechanics in introductory physics in the context of experiential learning. The four City University of New York designated experiential learning actions, namely, to increase knowledge, to develop skills, to clarify values, and to develop individual capacity have been implemented in terms of increasing fact and information processing memory capacity, exercising associative learning from experience, conducting critical thinking in synthesis and evaluation, and engaging causal reasoning with an understanding of a mechanism based on analysis such as graphical solutions. Asking a STEM student to create a numerical example when given a verbal description of a physical event and the reverse strategy of asking a student to provide a written description for a slight modification of a computation could be used to assess the feedback inquiry capability in the development of an innovative mindset. Physics experiential learning examples are presented.

Keywords

Associative learning, algebraic scale graphical solution, mechanism based causal reasoning,

Introduction

The City University of New York CUNY has been working on providing experiential learning opportunities to all its students¹. The CUNY definition has four actions, namely, to increase knowledge, to develop skills, to clarify values, and to develop individual capacity (page 4 of Reference One). Classroom integration was proposed “to identify coursework-based models of experiential learning that have potential to be scaled to serve more students” (page 11 of Reference One). This paper addresses the general theme of experiential learning in terms of associative learning, causal reasoning with transferrable knowledge and analytical reasoning with several mechanisms, and critical thinking for the development of an innovative mindset. In particular the daily examples mapping onto experiential learning in physics is an important first step since physics serves as one of the foundation subjects for STEM education.

Associative learning and causal reasoning

The four CUNY designated actions, namely, to increase knowledge, to develop skills, to clarify values, and to develop individual capacity have been implemented in physics classes for engineering students and technology students in terms of increasing fact and information processing memory capacity, exercising associative learning from experience, conducting critical

thinking in synthesis and evaluation, and engaging causal reasoning with an understanding of a mechanism based on analysis. The fact memory belongs to long term memory and there is no shortcut other than practice. Working memory capacity for information processing can be maximized when a cognitive task becomes a long term memory task or procedural memory task. For example, the plugging in of a set of given numerical values in an equation should rely on long term memory such that the working memory capacity can be maximized for the related math manipulation. This paper focuses on the three remaining issues, namely, associative learning from daily experience, critical thinking of a pertinent parameter, and causal reasoning with a mechanism.

Experiential learning has an important associative learning component. Using the trend on a graph to understand time of flight would clarify the mechanism other than a math procedure of solving a quadratic equation. Daily experience would show that an object would need more initial velocity v_0 to reach ground when being thrown upward against gravity downward pulling (-9.8 m/s/s) at 120 meters below ground. The time of flight can be obtained directly when applying the quadratic equation formula to the kinematics quadratic equation in time expressed as $0.5*(-9.8)*t*t + v_0*t - 120 = 0$. A graph of vertical height versus time together with a graph of horizontal distance versus time could be combined together to generate a graph of vertical height versus horizontal distance called trajectory. The association of a graph with meter versus second for a motion is intuitive for very technology student passing the math pre-requisite. However the generation of a trajectory graph by eliminating the time variable is not obvious for some technology students until after several repeated exercises. The critical thinking of the vertical height controlling of flight time could be made obvious by asking the students to focus on the vertical height versus time graph because of the changes in the parabola shape while the horizontal distance versus time is always linear in shape. The causation of higher v_0 for longer flight time can be deduced inductively after doing a few graphs. A deductive calculus presentation of differentiating v_0 with respect to flight time would belong to the academic learning approach², which is teaching time efficient for those students very familiar with calculus. Every student is expected to be familiar with the quadratic equation solution in algebra that time = $P + Q*\sqrt{-1}$ or $P - Q*\sqrt{-1}$ when $b*b$ is less than $4*a*c$ given the $a*x*x + b*x + c = 0$ format. The minimum initial velocity to reach ground from a depth of -120 m can be demonstrated by extrapolation (about 48 m/s) on a graph of $Q*Q$ versus initial velocity, shown in Figure 1. The trend represents a mechanism that corresponds to a causal reasoning process for individual capacity development, the last step in the CUNY experiential learning objectives discussed above. A deductive approach to find the minimum initial velocity using the math technique of solving for $b*b = 4*a*c$ making $Q = 0$ would transform the physics content to a math exercise in a student's mind. Whether experiential learning is "a complication of the obvious" from an academic learning perspective is an open question as far as we know. However the possibility of a different trend with a new slope would be useful to help a student to develop an innovative mindset with a realization of "the effect of changing gravity for Mars exploration".

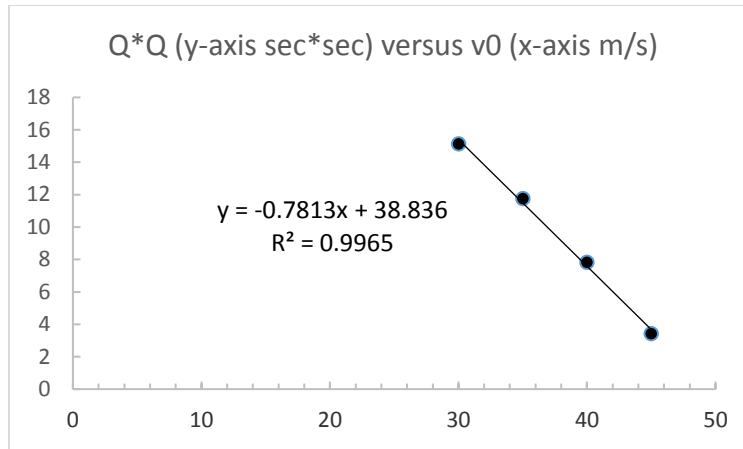


Figure 1: $Q*Q$ versus initial velocity for an object thrown upward from a well with depth -120 m.

A see-saw up and down swinging in a child-adult playing situation can be used to illustrate the concept of excess torque in terms of minimum and maximum torque values, consistent with differential calculus. A feedback question on how to control the torque via a spring-mass system in a robotic system would solicit innovative ideas obeying the principles of physics.

A wheel receiving an impulse on a non-smooth surface can be used to illustrate the non-uniform sliding speed versus time change with an integral concept that illustrates the calculus role in physics other than just a definite integral operation looking for a number. A feedback question on how to control sliding would require an understanding of the constraints.

Relative velocity transformation between reference frames in a collision can be illustrated with the experiential data observed while sitting on a moving bus. A feedback question on how to minimize the collision energy would encourage innovative ideas on AI controlled vehicles regarding velocities.

Transferrable knowledge

The delivery of experiential learning in physics learning could follow a basic pattern. A daily experience is transferred to become a trend represented by a graph, followed by a critical thinking identification of a pertinent parameter relevant to a selected objective. The trend would present a clear mechanism to facilitate a causal reasoning process for increasing individual capacity. A feedback application question to the daily experience could then be asked by an instructor for the development of an innovative mindset.

The quantitative description of a daily experience would rely on the skill of transferable knowledge. The basic words such as “presume” which depends on probability and “assume” which is independent of probability would needed to be taught first. The word “preposterous” is important such that a student would not “put a cart before a horse” and not be confused on “what drives what”. In the teaching of how to write a lab report discussion, an asking of a numerical example with a set of words given by an instructor was found to be helpful. When a student was asked to create a numerical example with the constraints of a set of given words as a required exercise before writing the discussion section, assessment data showed improvement where the

writing would include specific information related to data other than just generic statements that could be applied to any lab report. After acquiring this basic training in discussion writing, a genuine discussion of lab issues with data specificity would provide an opportunity for individual innovation in the context of resolution improvement and constraints. Such strategy could also be a first step to the development of an engineering mindset tuned onto lab experience and daily examples.

A mass sliding down a movable wedge from rest with final velocity values has been one of the most difficult problem in first year physics using momentum and energy conservation equations. Although a Youtube demonstration is available³, only about 20% physics students in our community college can follow the video academic learning deduction steps from theory to application. The use of an algebraic scale in a graphical method would generate an easier algorithm to solve for the answers within measurement errors. The momentum conservation can be represented by a drawing with a measurable relationship between the wedge and sliding object final velocity values, and the energy conservation equation would then be solved in a straight forwarded manner. The associative learning of standard vector drawing in relative velocity textbook examples and a critical thinking process of using an algebraic scale constitute the essence of such an algorithm in experiential learning. The mechanism in causal reasoning would then be clearly illustrated in the vector drawing. For example, a 3-kg object sliding down a 7-kg 35-deg wedge with zero friction everywhere can be solved within measurement error using an algebraic scale. Let wedge moves with velocity U m/s to the right. Then the effective velocity vector of the 3-kg object V m/s would obey the relationship $V' + U = V$ with V' being the velocity along the movable wedge slant surface. The horizontal x-axis momentum must be zero sine there is no horizontal external force. The expression $7*U = 3*V_x$ with V_x as the horizontal component so that $U/V_x = 3/7$. Let U be represented by a 3-cm vector drawing, then V_x must be represented by a 7-cm vector drawing. The drawings of a 35-degree vector for V' and a vertical 90-degree vector for V_y would result in a triangle with $U + V_x$ as the base of the triangle, shown in Figure 2.

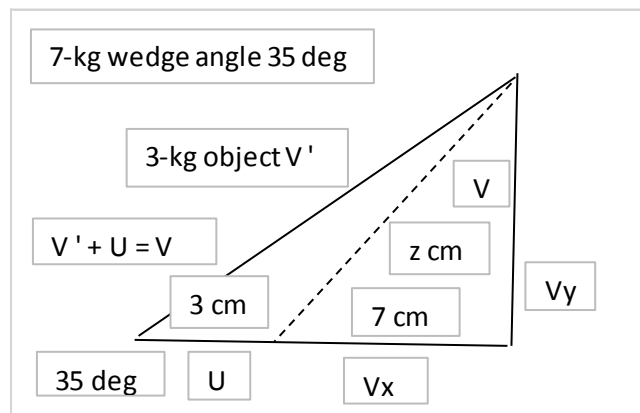


Figure 2: Velocity diagram for the problem of 3-kg object sliding down a 7-kg wedge with zero friction everywhere.

Connecting a line from the top vertex to the base line at the point where U and V_x meet would give the vector V , say z -cm, shown in Figure 2. Using proportionality, if $U = 3$ cm and $V = z$

cm, then $V = (z/3)*U$. Together with the energy equation of $1/2 * 3* V*V + 1/2 * 7* U*U = 3*(9.8)*(wedge\ height)$, the movable wedge velocity U can be calculated with the measured value of z and given height of the movable wedge.

Furthermore geometry familiarity with transferable knowledge is useful in doing orbital velocity vector problems in the chapter on gravitation. The orbital velocity vectors would form a circle⁴, and our assessment data showed that engineering students did better in questions involving $V_a*V_p = V_b*V_b$ using the circle geometry (with V_a and V_p magnitudes serving as diameter) rather than using conservation laws in energy and angular momentum; when V_a , V_p and V_b represent the velocity magnitudes at slow-aphelion, fast-perihelion, semi-minor axis positions respectively.

Discussion

Learning is not an easy task as confirmed by a recent report on neural reassociation⁵. Neuroscience data showed that the animal brain would use the already available neural patterns to learn a new task without neural optimization and explain the difficulty for achieving high proficiency in a short time period. Another recent MRI data based learning model explained that the learning of a word has a rapid association to an object in the context of propose but requires a subsequent verification (PbV model)⁶. The principle of experiential learning echoes well with the neural strategies developed through evolution. The experiential learning in physics lab setting is a sound presumption especially when uncertainty estimation is emphasized with applicability to engineering situations. A Force Table Lab with several forces in equilibrium carries the cosine similarity function concept, which is applicable as a kernel method in machine learning. It is relatively time consuming in the implementation of experiential learning in a lecture setting when compared to academic learning, but experiential learning in lecture does provide an interface between daily examples and physics. The experiential learning in kinematics in the lecture session serves as a threshold measure such that C/D grade students in an academic learning setting with theory as the first learning element would have an alternative vehicle to reach a meaningful passing grade. A 35% experiential learning in a 3-credit lecture combined with 100% 1-credit lab would add up to about 50% experiential learning in a 4-credit course. The feedback inquiry after causal reasoning would serve as an important element in the development of an innovative mindset for all students in experiential learning. Those A/B grade students who are capable of learning causal reasoning from theory which carries the prediction/forecast feature in an academic learning setting would still learn from an experiential learning setting. The focus on the “quantitative conversion exercise” of a slightly more complex daily example in response to a feedback inquiry would cultivate “generating more problems for solving”; consistent with the innovation article on Harvard Business Review that innovation is about problem solving and not ideas⁷. If the recent finding of a 50% genetic contribution to intelligence continues to hold up in future investigations, experiential learning could replace academic learning for the delivery of education to first generation college students⁸.

Experiential learning assessment tasks could include the writing a paragraph about a daily example for a numerical computation, the identification a pertinent parameter that controls an observable in that daily example, the production of a trend measure to demonstrate causal reasoning, the using of the trend as a mechanism to explain a similar daily example with a slight change in one input value, and the answering a feedback inquiry with a slightly more complex

daily example. An assessment rubric example for the experiential learning of the distance equation $x = v_0*t + 0.5*a*t*t + x_0$ applicable to an object being thrown upward is shown in Table 1. The input parameters of initial velocity v_0 , constant acceleration a , time interval t and initial distance x_0 carry writing description for a given set of input numerical values. The asking of a paragraph for distance equation and the identification of the most pertinent input for long time duration could be used to assess associative learning. The asking of a trend could be used to assess critical thinking of a mechanism related to causal reasoning. The asking of a paragraph for situation with 2 objects could be used to assess a feedback inquiry for the development of an engineering mindset. Scoring could be performed when assigning Highly Competent = 1, Competent = 0.8 and Needs Improvement = 0.6. Using a 0.75 average score as a benchmark, about 40% students in calculus physics (N = 44) and 15% students in technology physics (N = 45) passed the experiential learning assessment.

Table 1: An experiential learning assessment rubric.

Deliverable	Highly Competent	Competent	Needs improvement
Paragraph for distance equation 20%	All 4 inputs, v_0 , a , x , and t are included in paragraph	One input was missing	Two or more inputs were missing
Which input contributes the most for long time interval 20%	Acceleration “ a ”	Both v_0 and “ a ” contribute equally	Initial distance x_0 and/or initial velocity v_0
Trend graph of v_0 versus x_0 20%	Correct graph with all correct labels and displayed trend	Correct displayed trend on graph but with one wrong label	Wrong displayed trend, or correct trend with 2 or more wrong labels
Paragraph for smaller “ a ” 20%	Correct description of a smaller “ a ” example, consistent with physical laws	One unlikely assumption but no physical law was broken	The given example violates physical laws and could not have happened
Paragraph for situation with 2 objects 20%	2 objects sharing a single input parameter	2 objects with same (v_0, t), or (a, x_0), etc	2 objects with same (v_0, a, t, x_0), or 2 objects sharing zero input parameters

Conclusions

Experiential learning uses transferrable knowledge to understand a mechanism beyond associative learning in support of causal reasoning. Future studies could include an investigation of the transition from causal reasoning to analytical reasoning based on several mechanisms, etc.

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