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Assessment of working memory utilization improvement strategies for engineering and technology ESL students learning physics

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Assessment of working memory utilization improvement strategies for engineering and technology ESL students in the learning of physics

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Abstract

Working memory utilization improvement strategies in a flipped class environment, where the lowest cognitive level equals memorization in the Bloom's taxonomy, have been implemented for helping the learning of physics in engineering and technology ESL students. The recent discovery that a group consisting of engineering students in an urban university would use episodic memory when learning physics, in addition to the expected use of the semantic memory, has been applied to the teaching ESL engineering and technology students in an urban community college in New York City. The assessment results showed an improved working memory utilization when students were encouraged to use their mother-tongues in recalling the episodic memory. The strategic use of mother-tongue in terms of cognitive offloading and working memory utilization in the learning of physics by engineering and technology ESL students is discussed, together with the use of regression Cook's distance in the assessment model.

Keywords

Working memory, regression Cook's distance, free body diagram, episodic memory.

Introduction

Bloom's taxonomy places memorization as the lowest cognitive level. A flipped classroom would ask students to learn a topic first time as a homework reading assignment and to learn the higher cognitive levels in the classroom setting. The transitions to the various upper levels in the Bloom's taxonomy pyramid, shown in the Vanderbilt flipped class webpage have been emphasized with graphical reasoning together with Google Translate technology assisted thinking[1]. The pyramid has six layers, namely, remembering (or memory recalling), understanding, applying, analyzing, evaluating, and creating. The keywords in the Bloom's taxonomy verb chart in The University of Arkansas Innovation and Pedagogy Support webpage have been found to be useful for learning lectures and lab report writing as well[2]. The recent discovery that a group consisting of engineering students learning physics in Florida International University would use episodic memory, in addition to the expected use of the semantic memory, has been applied to the teaching of engineering and technology classes with ESL students in an urban community college in New York City[3-5]. The teaching application was based on the neuroscience discoveries of episodic and semantic memories, the first layer in Bloom's taxonomy. The interdependence of episodic memory for events and semantic memory for general knowledge such as equations and diagrams has been reviewed[6]. Events carrying the temporal-spatial relations are stored in episodic memory while the use of language is indicative of a functional semantic memory. Episodic memory impairments deduced from verbal episodic memory assessment scores are used for early dementia onset classification[7]. Active learning experience enriches episodic memory which contributes to the formation of new semantic memory[8]. A student in a physics class is expected to link the episodic memory in active classroom learning with the semantic memory of facts. Whether working memory utilization would affect the linkage between episodic and semantic memories in physics learning is an important issue. The implementation strategy for working memory utilization improvement involves the demarcation of the episodic memory in active learning and semantic memory in the pre-requisite mathematics.

Implementation

The problem solving of a 2-body system such as police-truck-chasing or student-student-jogging in the first week of teaching kinematics would engage both episodic and semantic memories. For an ESL student, the use of his/her mother tongue in recalling the episodic memory while doing a flipped class homework assignment would reduce the cognitive load when engaging the semantic memory of algebra and calculus in the classroom.

When there is one constant force and one object with constant mass, the "F = ma" application has little cognitive learning according to the Bloom's taxonomy with analysis as the fourth layer. The most simple 2-body system is likely to be the Atwood machine with 2 objects connected together via a negligible mass pulley. A free body diagram for an object of the Atwood machine must start with a dot/cross as that object. The second step of sketching the forces would be quite simple in terms of visual geometry. The string contact force in this case is upward while the non-contact weight is downward. The third step of labeling the forces with the maximum numerical information using a translation process of algebra symbols to arithmetic symbols would be a crucial step to promote cognitive offloading in perception theory when transforming the free body diagram to an equation [9, 10]. Basically a generic free body diagram in a textbook would become a numerical working diagram specific to the active learning classroom situation. The spatial reasoning with maximum numerical information will help the transformation process in generating two simultaneous equations in the Atwood machine situation. Drawing free body diagram to scale is an effective way to engage each student in active learning. The transformation is modeled as the linkage between the episodic memory in free body diagram active learning and the equations in semantic memory. The concept of translation was emphasized in teaching the students to incorporate the numerical values in the free body diagram. An ESL college student is usually bilingual and bi-literate and the explanation of free body diagram in terms of the translational and transformational processes would demystify the power of the free body diagram in terms of learning strategies based on neuroscience findings. Native English Language students also would benefit from such translation-transformation explanation in the free body diagram because college education usually involves the learning of a foreign language.

The second type of questions would involve tilted forces, other than just being either vertical or horizontal, in the context of contact forces. The usual "F = ma" lab, with a hanging weight pulling a horizontally positioned mass via a pulley setup, would have two free body diagrams requiring one of the Atwood machine's objects to be positioned horizontally. The modification of the free body diagram for one of the Atwood objects would require the spatial reasoning of the friction and string horizontal forces in addition to the vertical weight. Such modification could be reasoned as a modifier requirement encountered in translation in which additional words in Language-1 (L1) are need to translate a single word in Language-2 (L2).

The third type of questions involve those cases in which two different physics problems would share exactly same free body diagrams, and the use of the translation concept would be most appropriate. Pushing on a 3-block system horizontally is exactly the same as the chute-chute train problem, for example. Cognitively connecting physics problems with the translational and transformational concepts explicitly would engage learning at higher cognitive levels in the Bloom's taxonomy, not to mention the removal of negative affective issues such as fear or anxiety.

The three types of questions discussed above were used to train students in the demarcation of the episodic memory in the free body diagram and semantic memory in the pre-requisite mathematics. The hypothesis of using translation and transformation to detail the procedure of solving a physics problem would activate the language semantic process and free up the working memory to do mathematics is an important issue in education. Although a clinical MRI proof that such analogous reasoning would free up working memory in active learning for the generation of equations is not available yet, the assessment results on students' deliverables could still be used to advocate such hypothesis.

Assessment Results and Discussion

A physics problem with a force pushing on a large block with a small block in front shown in Figure 1 was assessed. The assessed 2-body system was a large block accelerating with a small block in front without touching the ground. The corresponding assessment rubric is shown in Table 1. The participants are students. Scoring was performed by assigning Highly Competent = 10-9, Competent = 8-7 and Needs Improvement 6-0. A typical "F = ma" problem for a 2-body system is shown in Figure 1.

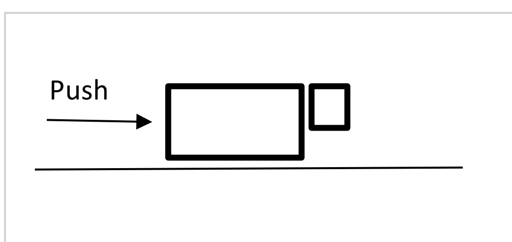

Figure 1: A sketch of the physics problem with a force pushing on a large block with a small block in front

Table 1: Assessment rubric

Deliverable	Highly competent	Competent	Needs Improvement
Free body diagrams for two objects 25%	Provided two clear and correct diagrams with all the forces except one or two	Contained three to four mistakes in the two diagrams	Contained four or more mistakes in the two diagrams
Free body diagram numerical translation 25%	Provided a clear translation of the given numerical values in the free body diagram	Contained one mistake	Contained two or more mistakes
F = ma equation 35% for tech (25% for engr)	Provided a clear and correct transformation of the two diagrams into two equations	Contained one mistake	Contained two or more mistakes
Adjusted values in ill-posted acceleration 15% for tech (25% for engr)	Provided a range of acceleration values so that the small block in front would not fall down	Provided one new acceleration value so that the small block in front would not fall down	Provided no value

In Figure 2, the scores along the x-axis are evaluation scores from free body diagram construction with the translation of the given numerical information, and the scores along the y-axis are evaluation scores from the transformation of the free body diagrams into the appropriate equations.

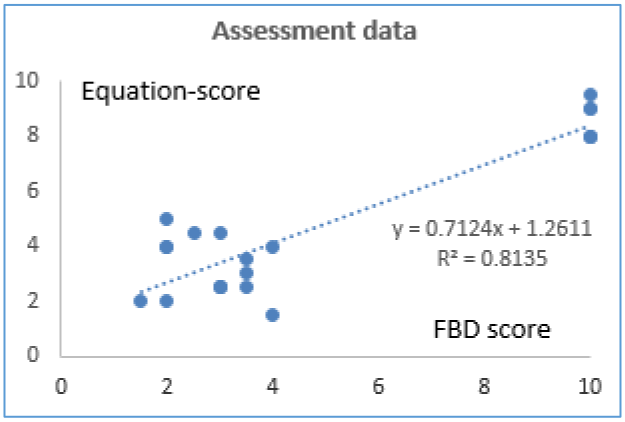

Figure 2: The regression of the technology physics assessment data for the physics problem illustrated in Figure 1 (N= 21).

The two data clusters shown in Figure 2 clearly showed two populations for a Physics I Mechanics class of technology students (N = 21 with 6 bi-literate students having the highest six scores). The Cook's distance shown in Figure 3 would quantify the separation of the clusters. The use of histogram would be possible only with a large population of Physics I Mechanics students in a large lecture hall setting with graduate students as teaching assistants, which is not the case in our community college. The Cook's distance could be used as a marker for the assessment of improvement in a longitudinal study when interventions such as linking to a language class is implemented.

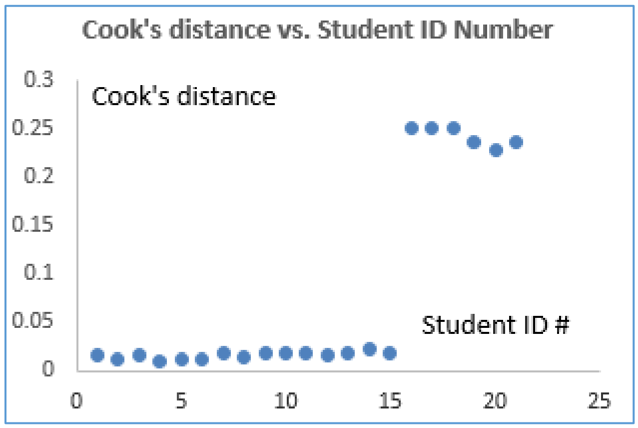

Figure 3: The Cook's distance of the regression data shown in Figure 2 with Student ID Number assigned from lowest FBD score of 1 to highest FBD score of 21.

Similar assessment performed in a Calculus Physics I Mechanics class for engineering students did not show two clusters, shown in Figure 4. The class (N = 23) had more than 50% bi-literate students in which about 25% were international students.

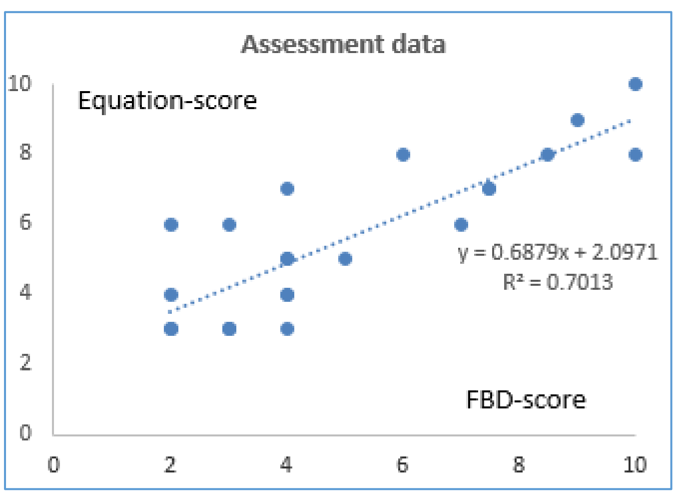

Figure 4: The regression of the calculus physics class assessment data for the physics problem illustrated in Figure 1 (N= 23).

Taking together, the episodic memory in FBD construction and semantic memory in equation formulation would help bi-literate technology students to answer the assessed tasks in Physics I Mechanics. On the other hand, the assessed mono-lingual students in the same technology class appeared to show a negligible correlation at R-sq at 0.035 with a negative slope of -0.025 (N = 15), consistent with an interpretation of memory overloading that the free body diagram task (episodic memory related) had interfered with the equation task (sematic memory related). Another interpretation is that the studied bi-literate technology students were ill-advised in taking algebra physics when they could be taking calculus physics in engineering programs.

In comparison, the Calculus Physics I Mechanics class sub-group data for those having FBD scores less than 7.5 still have a positive regression slope of 0.62 (R-sq = 0.30, N =17), suggesting that the low scores were not related to working memory capacity. The inference that the studied subgroup students did not need cognitive offloading strategy in doing the calculus physics assessment tasks would be consistently with the expectation of having more working memory for handling calculus. The recent discovery that olfactory identification correlates with spatial memory in humans could lead to new ways in the teaching of free body diagrams, given that short-term spatial memory has been studied as part of the episodic memory in virtual reality research [11, 12]. A recent MRI study showed that the brain networks could adjust themselves in reading, and a recent transcranial electrical simulation study showed positive result on creativity [13, 14]. A recent report showed that neurons of the studied C-elegans could exhibit spiking action potential signals like a human brain. All of these advances would facilitate the understanding of the human brain computation mechanism for education strategy improvement, together with the associated ethical issues [15, 16].

Conclusions

The assessment project examined the effect of using working memory utilization improvement strategies in terms of a clear demarcation of episodic memory in free body diagram construction and semantic memory in equation building in engineering and technology introductory physics classes. Within a technology class, the ESL students having familiarly in translation were deemed to be a separate group as indicated by the regression Cook's distance in the assessment data. The same assessment task for the calculus physics students majoring in engineering showed only one group/population even though the class had twice as many bi-literate students. Whether bi-literacy could predict physics learning is another interesting hypothesis, especially when languages would include music, sign language, etc. Obviously engineering had predated science which was born from astronomy with instrumentation. The existence of an engineering language that engages innovation could be the basis of the fundamental reason that enables experiential learning through the use of experiments. Future studies could include the assessments with tasks taken from vector examples in electricity and magnetism.

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