Global Journal of Engineering Education

Correlation between students' motivated strategies for learning and academic achievement in an engineering dynamics course

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ABSTRACT: The objective of the present study is to investigate whether there exists a statistically significant correlation between students' motivated strategies for learning and students' academic achievement in an engineering dynamics course. Students' motivated strategies for learning were measured by a Motivated Strategies for Learning Questionnaire (MSLQ) survey. Students' academic achievement was measured by their dynamics examination scores. A total of 71 engineering undergraduates participated in this study. The results of statistical correlation analysis show that students' dynamics examination scores were statistically significantly correlated to a sub-scale of MSLQ: students' self-efficacy for learning and performance ($r = 0.55$, $p < 0.01$). Methods on how to improve students' self-efficacy for learning and performance are also discussed.

Keywords: Students' motivated strategies for learning, academic achievement, correlation, engineering dynamics

INTRODUCTION

Engineering Dynamics

Engineering Dynamics is a high-enrolment, high-impact and core course that nearly all undergraduate students in mechanical, aerospace, civil, biological and biomedical engineering programmes are required to take [1-3]. However, this sophomore-level course is also widely regarded as one of the most difficult courses to succeed in [4-7], because it covers numerous foundational engineering concepts (e.g. displacement and velocity, force and acceleration, work and energy, impulse and momentum, and vibration) and is a prerequisite for many subsequent advanced courses, such as machine design, advanced structural design and advanced dynamics.

Factors Affecting Students' Academic Achievement

Research evidence has shown that students' academic achievement is affected not only by cognitive factors [8-10], e.g. cognitive abilities, but also by affective factors, such as motivation, interest and learning strategies [11-14]. For example, if a student is deeply interested in a particular learning topic and is highly self-motivated, the student would be willing to spend a significant amount of time and effort in learning. Most probably, this student would learn more than other students who lack interest and motivation.

Relevant literature has reported that students' motivated strategies for learning is statistically significant in correlation to students' academic achievement on many subject matters in STEM (science, technology, engineering and mathematics) disciplines [15-17]. For example, Jin et al found that motivation and leadership were two important affective factors that determined engineering students' retention and grade point average (GPA) in their first year of undergraduate study [16]. In a study of a college physics course, Lynch found that students' semester grade was positively correlated with students' self-efficacy, both intrinsic and extrinsic motivation, and task value [17].

The author of this article has conducted an extensive literature review using a variety of popular databases, including the Education Resources Information Center, Science Citation Index, Social Science Citation Index, Engineering Citation Index, Academic Search Premier, the ASEE annual conference proceedings (1995-2013) and the ASEE/IEEE Frontier in Education conference proceedings (1995-2013). The results of this literature review show that little research has been conducted to investigate whether the correlation between students' motivated strategies for learning and students' academic achievement also exists in any engineering dynamics courses.

The Motivated Strategies for Learning Questionnaire (MSLQ)

The Motivated Strategies for Learning Questionnaire (MSLQ) is a 81-item self-report instrument developed at the University of Michigan for assessing college students' motivational orientations and their use of different learning strategies in a college course [18][19]. The 81-items are categorised into two scales: the motivation scale and the learning strategies scale. Each scale consists of a set of sub-scales. The motivation scale consists of 31 items assessing students' goals and value beliefs, their beliefs about their skills to succeed and their anxiety about tests. The learning strategies scale includes 31 items regarding students' use of different cognitive and meta-cognitive strategies, and 19 items concerning student management of different resources [18][19].

Pintrich et al confirmed that scale reliabilities of the MSLQ were robust and that the instrument had reasonable predictive validity [20]. The MSLQ has been widely adopted in studying the impacts of students' motivational orientations and use of different learning strategies on their performances [17-21].

The Objective, Scope and Structure of the Present Study

The objective of the present study is to investigate whether there exists a statistically significant correlation between students' motivated strategies for learning (measured by MSLQ at the end of the semester) and students' academic achievement (measured by students' examination scores) in an engineering dynamics course. A total of 71 engineering undergraduates (including 62 male and nine female students) participated in the present study. In a recent semester, these students took an engineering dynamics course from the author of this article. During the semester, students took three mid-term examinations and one final comprehensive examination. At the end of the semester, students responded to the MSLQ survey. A statistical correlation analysis was conducted between motivated strategies for learning and academic achievement.

The scope of the present study is limited in studying the correlation between students' motivated strategies for learning (measured at the end of the semester) and students' academic achievement, and does not include study on how a student's motivation and learning strategies change over the semester. It is true that student's motivation and learning strategies may increase or decrease over the semester. Although the instructor (i.e. the author of this article) applied a variety of active learning approaches (such as clickers, as well as computer simulation and animation) throughout the semester, no measurements were taken to measure if students' MSQL scores varied over the semester. These measurements will be taken in a future study.

The remainder of this article is structured as follows. First, the research method and data collection are described in detail, including student participants and a set of dynamics examinations employed in the present study. Then, research findings from statistical correlation analysis are presented. The results show that students' dynamics examination scores were statistically significantly correlated to students' self-efficacy for learning and performance ($r = 0.55$, $p < 0.01$). Methods on how to improve students' self-efficacy for learning and performance are also discussed. Finally, conclusions are made at the end of the article.

RESEARCH METHOD AND DATA COLLECTION

Student Participants

A total of 71 students who took a dynamics course from the author of this article in a recent semester participated in the present study. Table 1 shows student demographics, where MAE stands for mechanical and aerospace engineering, CEE for civil and environmental engineering, BE for biological engineering, and other for biological engineering, general engineering, pre-engineering, undeclared majors, etc. As seen from Table 1, the majority of student participants were from either a mechanical and aerospace engineering major (52.1%) or a civil and environmental engineering major (26.8%). The vast majority of students were males (87.3%), and females accounted for only 12.7%.

Table 1: Student demographics.

	Major				Gender	
	MAE	CEE	BE	Other	Male	Female
Total student participants (n = 71)	37 (52.1%)	19 (26.8%)	9 (12.7%)	6 (8.4%)	62 (87.3%)	9 (12.7%)

Dynamics Examinations

During the semester, students took four dynamics examinations: three mid-term examinations and the final comprehensive examination. These examinations assessed student learning outcomes on a variety of learning topics that were addressed in the course. Table 2 shows learning topics covered in each examination.

Table 2: Learning topics covered in each examination.

Examinations	Mid-term examination #1	Mid-term examination #2	Mid-term examination #3	Final comprehensive examination
Learning topics covered	Kinematics of a particle; Kinetics of a particle: force and acceleration	Kinetics of a particle: work and energy; Kinetics of a particle: impulse and momentum	Planar kinematics of a rigid body; Planar kinetics of a rigid body: force and acceleration	All previous learning topics; Planar kinetics of a rigid body: work and energy; Planar kinetics of a rigid body: impulse and momentum; Vibrations

Figure 1 shows a dynamics problem that was employed in the final comprehensive examination. The problem statement is: the ball B has a mass of 20kg and is attached to the end of a rod whose mass may be ignored. The rod is subjected to a torque M = 5tNm, where t is in seconds. The ball has a speed of 3m/s when t = 0. Determine the speed of the ball when t = 4 seconds.

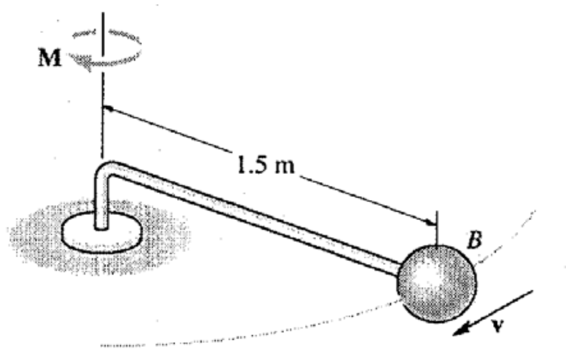

Figure 1: An example dynamics problem that was employed in the examination.

Based on three mid-term examination scores and the final examination score, the average examination score was calculated for each student participant. The maximum average score that a student could earn was 100, which would mean that the student earned a full 100 points on each of the four examinations. Figure 2 shows the histogram of all students' examination scores. This histogram represents a normal distribution of students' examination scores.

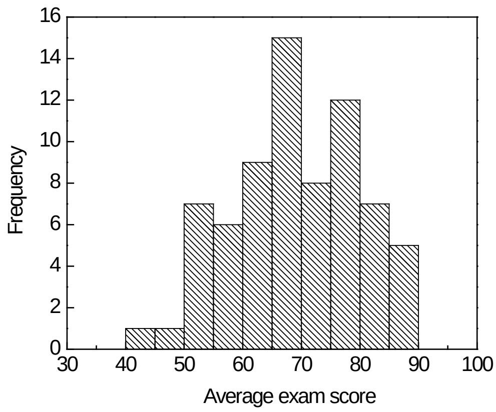

Figure 2: Histogram of students' examination scores.

MSLQ Survey

At the end of the semester, all student participants responded to the Motivated Strategies for Learning Questionnaire (MSLQ) survey that was described before. Statistical correlation analysis was conducted to study whether there is a statistically significant correlation between students' motivated strategies for learning and students' examination scores.

RESULTS AND ANALYSIS

Results

Table 3 shows Pearson's correlation coefficients between each MSLQ sub-scale and students' examination score. As seen from Table 3, students' examination scores are statistically significantly correlated to self-efficacy for learning and performance ($r = 0.55$, $p < 0.01$) and organisation ($r = -0.361$, $p < 0.01$).

Table 3: Correlation with students' examination scores.

MSLQ sub-scale	Pearson's correlation coefficient	Significance
Intrinsic goal orientation	0.098	0.414
Extrinsic goal orientation	0.160	0.182
Task value	0.094	0.438
Control of learning beliefs	0.220	0.066
Self-efficacy for learning and performance	0.550**	0.000
Test anxiety	-0.202	0.091
Rehearsal	-0.134	0.264
Elaboration	0.017	0.889
Organisation	-0.361**	0.002
Critical thinking	0.213	0.075
Meta-cognitive self-regulation	0.033	0.786
Time/study management	0.091	0.450
Effort regulation	0.060	0.618
Peer learning	-0.217	0.069

** Correlation is significant at the 0.01 level (2-tailed)

Self-efficacy for Learning and Performance

Self-efficacy for learning and performance is defined as *[one's] expectation of success and a self-appraisal of one's ability to master a task* [18]. The eight items that were employed in MSLQ to assess self-efficacy for learning and performance are listed in Table 4. Positive correlation (r = 0.55) between students' examination scores and self-efficacy for learning and performance seems to be reasonable.

Table 4: Survey items for assessing self-efficacy for learning and performance [18].

No.	Statements
1	I believe I will receive an excellent grade in this class.
2	I am certain I can understand the most difficult material presented in the readings for this course.
3	I am confident I can learn the basic concepts taught in this course.
4	I am confident I can understand the most complex material presented by the instructor in this course.
5	I am confident I can do an excellent job on the assignments and tests in this course.
6	I expect to do well in this class.
7	I am certain I can master the skills being taught in this class.
8	Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

Figure 3 further illustrates how students' examination scores are correlated to self-efficacy for learning and performance. Adjusted R2 for the fitted straight line shown in Figure 3 is 0.29. This means that 29% of students' examination scores can be explained from self-efficacy for learning and performance.

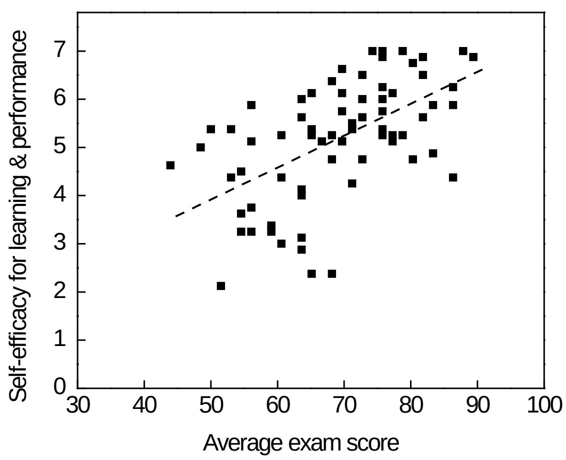

Figure 3: Self-efficacy for learning and performance versus students' examination scores.

Organisation

Organisation is defined as *...[one's skills to] select appropriate information and also construct connections among the information to be learned.* [18]. Negative correlation (r = -0.361) between students' examination scores and organisation seems to be unreasonable and contrary to common sense. Therefore, further investigation was conducted. Based on their average examination scores, the 71 student participants were divided into the three following groups:

- Top 30% students (n = 21): average examination score greater than or equal to 81;
- Middle 40% students (n=29): average examination score between 69.4 and 81;
- Bottom 30% students (n=21): average examination score less than or equal to 56.1.

Pearson's correlation coefficients were calculated for each student group, see Table 5.

Table 5: Correlation between organisation and students' examination scores.

Student categories	Pearson's correlation coefficient	Significance
Top 30% students (n = 21)	-0.154	0.506
Middle 40% students (n = 29)	0.212	0.269
Bottom 30% students (n = 21)	-0.526*	0.014
All students (n = 71)	-0.361**	0.002

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

As seen clearly from Table 5, it is the third group (i.e. bottom 30% of students, $r = -0.526$, $p < 0.05$) that determined the negative correlation ($r = -0.361$, $p < 0.01$) between students' examination scores and organisation for all 71 students. A possible explanation is that bottom students had a misunderstanding of their organisational skills. As Dunigan and Curry found in a research study on students' performance in a distance education course, what bottom students self-reported on the MSLQ survey might not truly reflect their organisational skills [22].

DISCUSSION

The research findings from the present study reveal the importance of students' self-efficacy for learning and performance in engineering dynamics. Therefore, improving students' self-efficacy is critical to improving students' academic achievement in engineering dynamics. Based on relevant literature on self-efficacy studies [23-25], as well as his own experience, the author of this article suggests the following methods, among many others, to improve students' self-efficacy:

For instructors:

- Create an encouraging and supportive learning environment both inside and outside the classroom to foster student success. For example, provide positive (rather than negative) feedback when students need help. More attention should be paid to those students with low self-efficacy;
- Set up role models (i.e. those students who have a high degree of self-efficacy and success) for other students to learn from;
- Be patient and give more time to students. Education is an art of slowness.

For students:

- Understand failure breeds success. Do not be discouraged by failures. Do not avoid challenging tasks;
- Learn to control emotional reactions and recover quickly from discouragements or failures;
- Develop deep interest in learning topics or activities. Understand that learning is always a process requiring commitment of time and effort;
- Set realistic and achievable learning goals;
- Be optimistic.

CONCLUSIONS

Students' academic achievement is affected not only by cognitive factors (such as cognitive abilities), but also by affective factors such as motivation, interest and learning strategies. Based on the results from 71 engineering undergraduates who recently took an engineering dynamics course, the present study reveals that students' dynamics examination scores were statistically significantly correlated to a sub-scale of MSLQ: students' self-efficacy for learning and performance ($r = 0.55$, $p < 0.01$).

However, a negative correlation ($r = -0.361$, $p < 0.01$) was found between students' examination scores and organisation because low-performing students misunderstood and did not correctly report their organisational skills. This negative correlation would be reduced if the sample size increases.

A variety of methods can be used by both instructors and students to improve self-efficacy. For example, instructors should create an encouraging and supportive learning environment both inside and outside the classroom to foster student success. Students should understand that failure breeds success, and not be discouraged by failures or avoid challenging tasks.

ACKNOWLEDGEMENTS

Part of this work is supported by the National Science Foundation under grant No. DUE 1244700.

REFERENCES

1. Hibbeler, R.C., *Engineering Mechanics Dynamics*. (13th Edn), Upper Saddle River, NJ: Pearson Prentice Hall, (2012).
2. Beer, F.P. Jr., Johnston, E.R. and Cornwell, P., Vector Mechanics for Engineers: Dynamics. (10th Edn), Columbus, OH: McGraw-Hill (2012).
3. Gray, L.G., Costanzo, F., Evans, D., Cornwell, P., Self, B. and Lane, J.L., The dynamics concept inventory assessment test: a progress report and some results. *Proc. 2005 ASEE Annual Conf. and Exposition*, Portland, OR, (2005).
4. Self, B.P., Widmann, J.M, Prince, M.J. and Georgette, J., Inquiry-based learning activities in dynamics. *Proc. 2013 ASEE Annual Conf. and Exposition*, Atlanta, GA (2013).
5. Fang, N., Students' perceptions of dynamics concept pairs and correlation with their problem-solving performance. *J. of Science Educ. and Technol.*, 21, **5**, 571-580 (2012).
6. Coller, B., First look at a video game for teaching dynamics. *Proc. 2011 ASEE Annual Conf. and Exposition*, Vancouver, BC, Canada (2011).
7. Stanley, R., An efficient way to increase the engineering student's fundamental understanding of particle kinematics and kinetics by using interactive web based animation software. *Computers in Educ.*, 18, 23-41 (2008).
8. Mayer, R.E., *Thinking, Problem Solving, Cognition.* New York, NY: W. H. Freeman and Company (1992).
9. Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H. and Krathwohl, D.R., *Taxonomy of Educational Objectives: The Classification of Educational Goals; Handbook I: Cognitive Domain.* New York, NY: Longmans, Green (1956).
10. Mayer, R.E., Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science* 26, **1-2**, 49-63 (1998).
11. Marra, R.M., Rodgers, K.A., Shen, D. and Bogue, B., Leaving engineering: a multi-year single institution study. *J. of Engng. Educ.*, 101, **1**, 6-27 (2012).
12. Schunk, D.H. and Zimmerman, B.J., *Motivation and Self-Regulated Learning: Theory, Research and Applications.* New York, NY: Routledge (2009).
13. Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J., Characteristics of freshman engineering students: models for determining student attrition in engineering. *J. of Engng. Educ.*, 86, **2**, 139-149 (1997).
14. Pintrich, P.R. and De Groot, E.V., Motivational and self-regulated learning components of classroom academic performance. *J. of Educational Psychology*, 82, **1**, 33-40 (1990).
15. Bandura, A., Self-efficacy mechanism in human agency. *American Psychologist*, 37, **2**, 122-147 (1982).
16. Jin, Q., Imbrie, P.K., Lin, J.J.J. and Chen, X.Y., A multi-outcome hybrid model for predicting student success in engineering. *Proc. 2011 ASEE Annual Conf. and Exposition*, Vancouver, BC, Canada (2011).
17. Lynch, D.J., Motivational beliefs and learning strategies as predictors of academic performance in college physics. *College Student J.*, 44, **4**, 920-927 (2010).
18. Pintrich, P.R., Smith, D.A.F., Garcia, T. and McKeachie, W.J., A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ), Report 91-B-004. Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning (1991).
19. Pintrich, P.R., Marx, R.W. and Boyle, R.B., Beyond cold conceptual change: the role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, 63, 167-199 (1993).
20. Pintrich, P.R., Smith, D.A.F., Garcia, T. and McKeachie, W.J., Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measure*, 53, **3**, 801-813 (1993).
21. Burlison, J.D., Murphy, C.S. and Dwyer, W.O., Evaluation of the Motivated Strategies for Learning Questionnaire for predicting academic performance in college students of varying scholastic aptitude. *College Student J.*, 43, **4**, 1313-1323 (2009).
22. Dunigan, B. and Curry, K.J., Motivation and learning strategies of students in distance education. *J. of the Mississippi Academy of Sciences*, 51, **2**, 140-155 (2006).
23. Fantz, T.D., Siller, T.J. and DeMiranda, M.A., Pre-collegiate factors influencing the self-efficacy of engineering students. *J. of Engng. Educ.*, 100, **3**, 604-623 (2011).
24. Ahlgren, D. and Verner, I.M., Building self-efficacy in robotics education. *Proc. 2007 ASEE Annual Conf. and Exposition*, Honolulu, HI (2007).
25. Hutchinson, M., Follman, D., Sumpter, M. and Bodner, G., Factors influencing the self-efficacy beliefs of first year engineering students. *J. of Engng. Educ.*, 95, **1**, 39-47 (2006).

BIOGRAPHY

Ning Fang is an Associate Professor in the College of Engineering at Utah State University, USA. He has taught a variety of courses at both graduate and undergraduate levels, such as engineering dynamics, metal machining and design for manufacturing. His areas of interest include computer-assisted instructional technology, curricular reform in engineering education, the modelling and optimisation of manufacturing processes, and lean product design. He earned his PhD, MS and BS degrees in mechanical engineering and is the author of more than 60 technical papers published in refereed international journals and conference proceedings. He is a Senior Member of the Society for Manufacturing Engineering and a member of the American Society of Mechanical Engineers. He is also a member of the American Society for Engineering Education and a member of the American Educational Research Association.