2019 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
Science, Technology & Engineering, Arts, Mathematics & Education June 5 - 7, 2019
Hawaii Prince Hotel Waikiki, Honolulu, Hawaii

Using Peer Assisted Learing in an Engineering Technology Course

Cioc, Carmen et al
University of Toledo
Toledo, Ohio

Dr. Carmen Cioc
Engineering Technology Department
The University of Toledo
Toledo, Ohio

Dr. Noela Haughton
Educational Foundation & Leadership Department
The University of Toledo
Toledo, Ohio

Mr. Christopher Wojciechowski
Educational Foundation & Leadership Department
The University of Toledo
Toledo, Ohio

Dr. Sorin Cioc
Mechanical, Industrial, and Manufacturing Engineering Department
The University of Toledo
Toledo, Ohio

Using Peer Assisted Learning in an Engineering Technology Course

Synopsis:

The Engineering Mechanics Statics course is one of the fundamental courses in our Mechanical Engineering Technology program and is a prerequisite course for the Strengths of Materials and Dynamics courses. The primary objective of the course is to provide the ability to investigate and solve trusses, frames, and mechanisms under static equilibrium conditions. A good understanding of these concepts is essential for solving a wide range of mechanics problems.

Using Peer Assisted Learning in an Engineering Technology Course

Synopsis

The Engineering Mechanics Statics course is one of the fundamental courses in our Mechanical Engineering Technology program and is a prerequisite course for the Strengths of Materials and Dynamics courses. The primary objective of the course is to provide the ability to investigate and solve trusses, frames, and mechanisms under static equilibrium conditions. A good understanding of these concepts is essential for solving a wide range of mechanics problems.

The paper describes the authors' effort to enhance the students' knowledge of statics concepts through a variety of in-class activities, including peer-assisted learning, in the form of in-class assignments solved by students in small groups. A minimum of 15 minutes per class were dedicated to such problem solving strategies, which was time well spent as the results showing the improved student's knowledge of the subject matter are extremely encouraging. In addition, to encourage participation of all students and discussions between the group's members, the students were required to submit at the end of the exercise a brief record of the conversations they held to solve the given problem.

This strategy was briefly introduced during the spring 2017 semester and was broadened in the spring 2018 semester. Results before and after such learning experiences are presented for different student learning outcomes. For example, on the topic of calculating the resultant of multiple concurrent forces, the class average during spring 2018 semester was 97% compared with 70% during spring 2017 and 62% for spring 2015. Spring 2015 serves as pre-PAL baseline. Benefits, limitations, and future directions are also discussed.

Background

Gains in retention are vital to the success of students, the success and rankings of universities, and thus, to the respective home countries at large. For example, approximately 50% to 85% of gross domestic product (GDP) growth in the United States is attributable to advancements in science and engineering (Augustine, 2012). Moreover, the economic growth attributable to STEM-related occupations (17%) is expected to out-pace those in non-STEM fields (9.8%) (Sununu & Cardona, 2013). Thus, the importance of the currency, relevance, and development of university-based engineering programs such as engineering mechanics are critical to this continuous growth, requiring a continuous improvement strategy. This strategy should necessarily focus on both academic and non-academic components such as statics coursework, communication, and collaboration. Continuous improvement requires an investment of time and formative exploration to enhance the pedagogical foundations of these courses through strategies such as active learning, peer instruction, and one-to-one tutoring (Bloom, 1984; Fagen, A.P., Crouch, C.H., and Mazur, E., 2002; Hendriksen, S.I, Yang, L., Love, B., Hall, M.C., 2005; Prince, 2004). Pedagogical improvements are ultimately financial investments, an example of which is the state of Kansas' 2012 investment of $10.5 million USD to increase the number of engineering graduates across its three state institutions by 60% over the next decade (Carpenter, 2011). With this investment come the expectation of effective professional preparation. The foundation of effective professional preparation requires mastery of foundational content. However, sometimes students struggle with core concepts, which in turn, negatively impacts their performance in advance courses, their academic progress, and subsequently, their retention, which, ultimately impacts the university's success and thus ranking. Therefore, effective preparation must also include the identification of these difficult content areas followed by the development and implementation of effective pedagogical interventions and instructional support. One known example of critical content area that universities continue to focus on is Engineering Mechanics and Statics (Statics), which is a necessary pre-requisite for advanced course work, like Engineering Mechanics Dynamics or Strength of Materials, and effective performance in applied settings. A 2.5-year study at Wichita State revealed a 36% failure rate in Statics (Myose, R., Raza, S., Hoffmann, K., and Ghoddoussi, A., 2014). Failure rates in Statics from the 2000 to 2002 academic years at California State Polytechnic University in Pomona ranged from 40% to 44% (Rezaei, A., 2007). A University of Cincinnati study of the effects of instructional formats led to positive results, but still with a reported failure rate of 24% (Rutz et al., 2003).

Much of the failure in Statics is attributed to misconceptions regarding basic content such as the relationship between forces, and these and other misconceptions are carried into other introductory courses (Halloun, I. Hestenes, D., 1985). Over time, efforts have been made to identify these misconceptions (Hestenes, D., Wells, M., and Swackhamer, G, 1992; Steif, 2004). A separate remediation course for these foundational misconceptions cannot be easily added to the curricula. Existing core course in Engineering are comprised of a mixture of physical-science-related abstract and theoretical disciplines. For example, students must apply previously learned prerequisite coursework related to topics such as physics and trigonometry to solve practical problems under specific conditions. The pace of the coursework and the performance expectations to apply previously-learned core content precludes the re-teaching of rudimentary concepts at the expense of scare course time.

Consequently, students that struggle with foundational concepts from prerequisite coursework such as Technical Physics Mechanics, may not be capable of maintaining pace with their more advanced classmates, resulting in a lack of academic progress and possible retention issues (Bernhold, L., Spurlin, J.E., and Anson, C, 2007). Performance in statics courses is a strong predictor of retention in the engineering majors and of results in future engineering courses (Takahira, S., Goodings, D. J., and Byrnes, J. P., 1998).

The above-mentioned issues exist in the current university where Engineering Technology students registered in an engineering mechanics statics course struggle to understand basic physics and engineering concepts such as finding the components of a force on an x- and y-axis or performing a simple basic truss analysis. The forgoing discussion is evidence that these student experiences are in alignment with the experiences of similar students at universities. A firm understanding of these core concepts and principles is essential for a wide range of real-world engineering applications. An active learning intervention using peer-assisted learning (PAL) strategies including collaboration and communication, were introduced to address the above-mentioned achievement gaps. These strategies are supported by prior research (Rohrbeck, C.A., Ginsburg-Block, M., Fantuzzo, J.W., and Miller, T.R., 2003). The purpose of this study is to describe the initial application and results of the implementation of PAL strategies in an engineering technology mechanics – statics course.

Professional preparation in Engineering has been moving to a collaborative model with multiple socio-technological dimensions, as part of learning to solve engineering problems cooperatively (Dym, C.L., Wesner, J.W., Winner, L., 2003). Current Accreditation Board for Engineering and Technology (ABET) standards specifically include student outcomes related to team-based communication and collaboration. The ability to engage in academic and non-academic discourse using the language of engineering, including physics and math concepts, is an additional indicator of learning and understanding. This includes oral and written communication to describe projects, limitations and constraints, models, and parameters in calculations (Dym, C.L., 1994). Group-based collaboration and communication support the development and application of engineering and mathematics vocabulary, which facilitates creative problem-solving within diverse teams, in current and future contexts (Mabogunje, A., and Leifer, L.J., 1997). Group-based collaboration and communication and PAL strategies have been shown before to increase engagement and further students' understanding in other STEM classroom settings (Obenland, C.A., Munson, A.H., and Hutchinson, J.S., 2013). However, there is still a lack of research on the use and efficacy of these strategies in the engineering classroom.

The current study is trying to respond to the following research question: "What impact will a peer assisted learning strategy have on the scores of students in the engineering statics classroom?" Implementation with a focus on ABET criteria could also provide a pathway for improving student outcomes related to solving engineering problems cooperatively by providing experience working within teams and communicating (ABET, 2017; Dym, C.L., 1994).

Research Methods and Procedures

Site and Participants

The site for this study is the Engineering Technology Department (ET) in the College of Engineering (COE), at The University of Toledo (UT). The COE is one of the largest colleges in terms of enrollment at UT and is comprised of six academic departments, including ET. The Department offers ABET-accredited professional engineering technology programs leading to the Bachelor of Science degree in five areas of study: Computer Science and Engineering Technology (CSET), Construction Engineering Technology (CET), Electrical Engineering Technology (EET), Information Technology (IT), and Mechanical Engineering Technology (MET). The largest program in the ET Department is the MET program, which enrolls approximately 400 undergraduate students. The MET student body is comprised of traditional students (18 to 24-year-olds) (40%), transfers (23%), internationals (7%), and non-traditional, returning adults (30%). This research focuses on core requirements in Statics, and thus, includes a cross-section of these sub-groups.

The Course

The Engineering Mechanics Statics course (MET 2100) is one of the core courses for the MET and EET programs, and it is one of the prerequisites for advanced courses including Strengths of Materials (MET 2120) and Dynamics (MET 3400). MET 2100 is a three-credit hour course that is offered during both the spring and fall semesters (15-weeks) as well as the summer semester (12-weeks). The course covers the fundamentals of static force analysis including: forces, moments, dry friction, free-body diagrams; static equilibrium applied to machines, mechanisms, trusses, and frames; and, center of gravity, centroids, and moments of inertia. The overarching goal of this course is to emphasize the application of basic principles to the solution of simplified engineering problems. A proficient grounding in these concepts is critical for solving a wide range of engineering mechanics problems, and therefore, is essential for success in advanced courses.

Curriculum Instructional Framework and Design

The curricular updates were informed by well-established instructional design theories and approaches, including inquiry-based and active learning. These learning approaches are associated with a range of strategies including project-based learning, problem-based learning, student-centeredness, collaboration, exploration of issues, negotiation, problem solving, flexible thinking, knowledge construction, scaffolding, lifelong learning, and presentation and communication (Avsec, S., and Kocijanic, S, 2016; Hannafin, M. J., and Land, S. M., 2012; Kim, M. C., and Hannafin, M. J, 2011; Jonassen, D.H., 2000; Mayer, R. E., and Wittrock, M. C., 2006; and Scardamalia, M., and Bereiter, C., 2010). Moving from a traditional instructional approach that relies on lecture and teacher-led problem solving to student-centered and active learning involves a deliberate shift in perspective and instructional approach that encompasses course design, assessment, and delivery decisions. These decisions require a course and curriculum view. At the course level, students are learning statics fundamentals, both conceptually and beginning to solve higher order, real-world problems related to structures and mechanisms. At the curriculum, proficiency in statics ensures alignment and preparation for advance course work in Dynamics and Strength of Materials.

The MET 2100 re-design was contextualized within a larger competency-based curriculum and course design model, as shown in Table 1. MET 2100 Learning Framework is an adaptation from the Ready Develop Integrate Perform (RDIP) Model, which describes a competency-based approach that informs course and program designs and related assessment activities, processes, and decisions (Haughton, N., 2017). The RDIP model integrates several learning frameworks including: Bloom's Cognitive Taxonomy (Bloom, B.S., and Krathwohl, D.R., 1956); The Conceptual Learning Model (U.S. Department of Education, n.d.; Voorhees, R.A., 2001); cross-functional competences (Rothwell, W.J., and Gaber, J. M, 2011); The Bologna Process and the Dublin Descriptors (ESG, 2015); and, Degree Qualifications Profiles (DQP) (Lumina, 2014). Learning experiences progress from readiness (*Ready*) to mastery (*Perform*), with Communication *and Collaboration* integrated throughout learning. The lens of the Bloom's Cognitive Taxonomy informs the incorporation of performance expectations and assessment at each competency progression. The current adaptation describes the assessment and learning framework for MET 2100. This course is a pre-requisite for coursework in Strengths of Materials and Dynamics.

Table 1: MET 2100 Learning Framework

	Competency Level	Course Performances & Assessment	MET 2100 Statics for Technology
Communicate and Collaborate	**Perform** Make judgments / real-world tasks	completion of advanced learning objectives. **sample assessments:** real-world focused project; presentation; internship	Upper level courses, like Strength of Materials: Design of Beams. Deflection of Beams.
	Integrate apply core knowledge & understanding	completion of mid-level, integrative learning objectives. **sample assessments:** module assessment, project components, concept maps	Analysis of trusses. Center of Gravity. Area Moments of Inertia
	Develop core knowledge & understanding	completion of low-level learning objectives. **sample assessments:** quizzes / chapter tests	Resultant and equilibrium of coplanar forces. Concurrent Spatial Force Systems
	Ready prerequisite knowledge, skills, abilities, etc.	completion of course prerequisites. **sample assessments:** prior course work, software skills, technical skills, & other competences	**course content:** PHYS 2020 Technical Physics Mechanics. Topics include measurement, statics, Newton's laws, friction, work, energy, power, impulse and momentum, and simple machines. Also, includes an integrated laboratory

Peer Assisted Learning Strategies

The integration of PAL and assessment strategies was influenced by the work of Black and William (2009), which identifies five key aspects of effective formative assessment: students clarify, share, and have understanding of learning intentions and criteria for success; students engineer effective classroom discussion/question/tasks that elicit evidence of learning;

students receive feedback to move forward; students are activated as instructional resources for one another; students are activated as owners of their own learning. Worksheets (response sheet) (Appendix 1) were developed to be used individually and collaboratively for problem solving. The worksheet contained conceptual prompts that are aligned with the statics course curriculum. The prompts provide scaffolds that help students identify the relationships between the different pieces of information and concepts required to solve a problem (Hiebert, J. et al., 1996). The students have autonomy in the collaborative problem-solving activities in two ways. Firstly, students develop group memberships. Secondly, each group chooses how to engage in the collaborative process by either individual then collaboration or collaboration only. This autonomy encourages students to develop leadership skills as well as adaptable multiple problem-solving strategies (Boaler, J., 1998).

As previously mentioned, the Engineering Mechanics Statics classroom is a space in which active learning strategies are implemented using a mixture of abstract physics and mathematical concepts to solve practical problems related to trusses, frames, and mechanisms under static equilibrium conditions. Also previously mentioned was the difficulty to implement remediation for under-performing students many of whom, bring misconceptions to the classroom. One PAL strategy, think-pair-share, focused small-group activities. This small-group collaboration supports remediation as students engage in problem-solving. This, in turn, mitigates the amount of time the instructor spends on remediation. The students with a greater understanding will be able to answer the questions, thus helping to close the learning gaps of their peers as needed (Dillon, J.T., 1984). Each small group reports their strategies and solutions at the end of the allowed time as part of a larger instructor-facilitated classroom discussion. PAL interventions are designed with the intent of enhancing learning and motivation, and consequently achievement, through peer-mediated teaching strategies (Rohrbeck, C.A., Ginsburg-Block, M., Fantuzzo, J.W., and Miller, T.R., 2003). The structure of the classroom tasks, peer evaluation techniques, and instructional formats of PAL are built on strategies identified to increase competence and autonomy (Ames, C., 1992).

PAL Implementation Procedures

PAL in our Engineering Mechanics Statics classroom followed the same strategy of using a think-pair-share session following the proposal of a statics problem broken down into multiple segments. Think-pair-share as a PAL activity has been shown to increase engagement and further student understanding in other classroom settings (Obenland, C.A., Munson, A.H., and Hutchinson, J.S., 2013; Rohrbeck, C.A., Ginsburg-Block, M., Fantuzzo, J.W., and Miller, T.R., 2003). Though rarely applied in an engineering setting, it is expected that PAL interventions will result in increased engagement and success for students across skill levels, including improving learning outcomes for both low-performing and advanced students.

One of the key components of the PAL format is the response sheet. The sheet is designed to structure student reporting of small-group collaborative conversations and problem-solving activities, including difficulties encountered and solutions implemented. These completed response sheets are used as evidence that the students are explaining and teaching concepts to each other (Slavin, R.E., Hurley, E.A., and Chamberlain, A., 2003). The conversations are important because students, while engaging in the academic discourse of engineering, increase their learning and understanding of core concepts (Webb, N.M., 1991). Within the Engineering Mechanics Statics classroom, specifically, the act of peer conversation of the material serves multiple purposes.

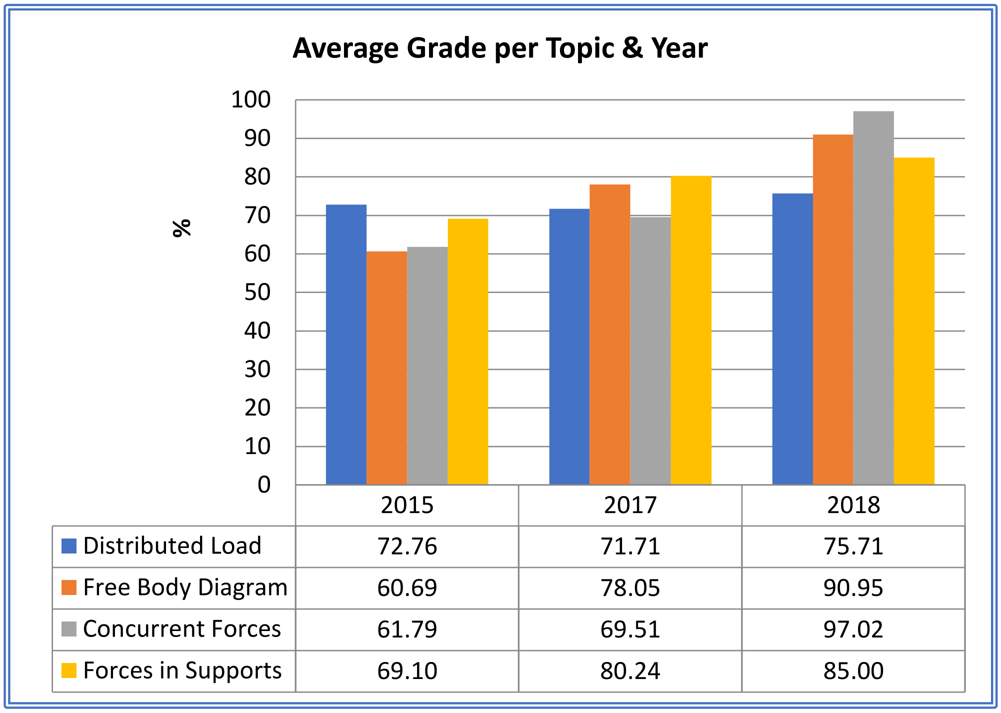
1. Teamwork. The practice of engineering is increasingly being recognized as a team process with multiple socio-technological dimensions. Therefore, engineering programs must prepare graduates to function effectively on collaborative teams to solve engineering problems (Dym, C.L., Wesner, J.W., Winner, L, 2003).

2. Communication. Effective communication skills are essential for the engineering profession. Learning and practicing to interact in classroom settings should improve communication skills, develop engineering and mathematics vocabulary, and increase creativity (Dym, C.L., 1994; Mabogunje, A., and Leifer, L.J., 1997).

The ABET general engineering criteria (ABET, 2017) specifically include student outcomes related to functioning on teams and communicating.

Results

The PAL strategies were piloted in spring 2017 and the implementation was broadened in the spring 2018 semester. The results are shown in Figure 1 in which spring 2015 serves as a pre-PAL baseline. On the topic of calculating the resultant of a number of concurrent coplanar forces: the spring 2018 results showed a class average of 97% compared with a class average of 70% in spring 2017 and 62% for spring 2015.



	2015	2017	2018
🟦 Distributed Load	72.76	71.71	75.71
🟧 Free Body Diagram	60.69	78.05	90.95
⬜ Concurrent Forces	61.79	69.51	97.02
🟨 Forces in Supports	69.10	80.24	85.00

Figure 1: Average grade distribution per content knowledge

On the topic of distributed load: the class average during spring 2018 semester was 76% compared with 72% during spring 2017 and 73% for spring 2015. On the topic of free body diagram: the class average during spring 2018 semester was 91% compared with 78% during spring 2017 and 61% for spring 2015. On the topic of concurrent forces: the class average during spring 2018 semester was 97% compared with 70% during spring 2017 and 62% for spring 2015. On the topic of reaction forces at supports: the class average during spring 2018 semester was 85% compared with 80% during spring 2017 and 69% for spring 2015.

There are still topics / subjects that need more work than others, like the truss analysis as shown in Figure 2. The results show an improvement though on average, students were are still not proficient as reflected by a minimum score of 75%.

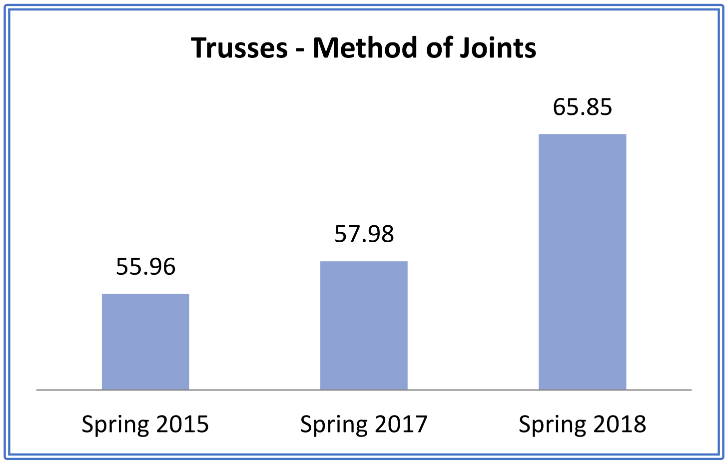


Figure 2: Average grade distribution for truss analysis content knowledge

An unexpected result was obtained for the area moment of inertia content topic. As seen from the Figure 3, the class average results for spring 2018 was significantly below the average class results as compared with previous semesters including spring 2014. The assessment problem during spring 2018 asked for the area moment of inertia with respect to a given non-centroidal x-axis. The majority of the students solve the problem for the area moment of inertia with respect to the centroidal x-axis, similar with several problems discussed in class. This misconception might have been uncovered has this topic been addressed in a PAL session.

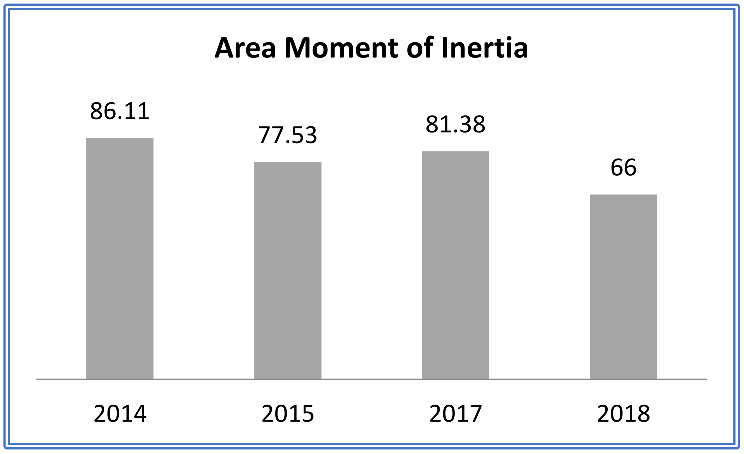


Figure 3: Average grade distribution for area moment of inertia content knowledge

The efficacy of the PAL strategy was observed over several workgroup problems aligned with the curriculum and using similar materials and assessments from prior semesters (Taras, M., 2005). On these assessments, students are given open ended opportunities to solve problems, where the exact strategy used to solve depends on the prior experience of the learner with the tasks presented. These assessments are used due to the cognitive complexity involved in solving work with multiple pathways to a solution, which allows students to demonstrate how their experience influences their learning (Linn, R.L., Baker, E.L., and Dunbar, S.B., 1991). The assessments were chosen over other forms of analysis of learning, such as surveys or end of course ratings, due to the relative credibility assessment analysis has with engineering professors (Wankat, P.C., Felder, R.M., Smith, K.A., Oreovicz, F.S., 2002).

Limitations related to the research context include relatively small class sizes, convenience samples, and the case study nature of the implementations. Additional limitations result from the nature of the classroom setting including the inability to control other influences on learning (Wankat, P.C., Felder, R.M., Smith, K.A., Oreovicz, F.S., 2002).

Conclusion

PAL strategies, even when implemented for a short period, show promise for increasing content knowledge through collaborative engagement. The current results support the potential benefits as described in Figure 4.

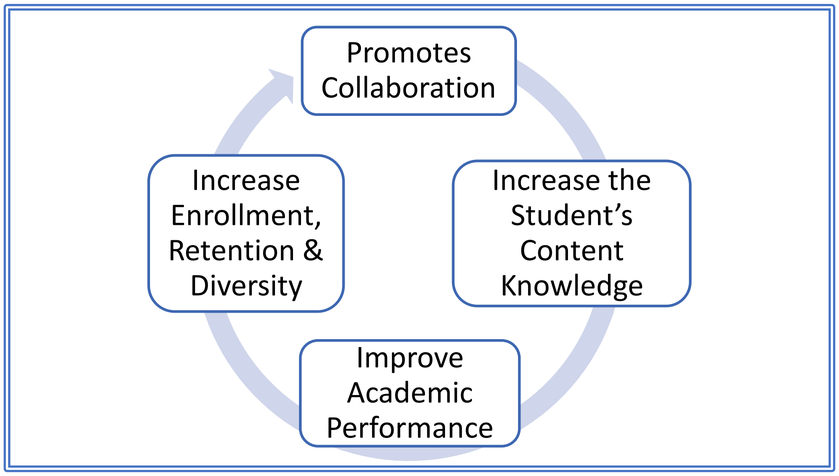


Figure 4: The benefits of using PAL

In addition, the practical benefits from the implementation of PAL strategies remove the need to add remedial content to the course as well as the need to add remedial courses to the curriculum. Moreover, the improved performance of most students is likely to improve retention across the board, including traditional and non-traditional students as well as underrepresented sub-groups.

References:

Augustine, N. “America's Education Problem Isn't Money, It's How We Spend It”, U.S. News and World Report, June 8, 2012

Sununu, J. and Cardona, M., “STEM fund key to U.S. global competitiveness,” The Hill Congressional Blog, June 12, 2013.

Bloom, B.S. “The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring”, Educational Researcher, Vol 13, pp. 4–16., 1984

Fagen, A.P., Crouch, C.H., and Mazur, E. “Peer Instruction: Results from a Range of Classrooms”, Physics Teacher; 40(4): 206–209. April 2002

Hendriksen, S.I, Yang, L., Love, B., Hall, M.C.” Assessing Academic Support: The Effects of Tutoring on Student Learning Outcomes”, Journal of College Reading Learning; Vol.35, pp.56–6, Spring 2005

Prince, M. “Does Active Learning Work? A review of the Research”, Journal of Engineering Education, Vol.93, Issue 3, pp.223-231, 2004

Carpenter, T., "Governor signs KPERS, engineering bills," Topeka Capital-Journal, May 25, 2011.

Myose, R., Raza, S., Hoffmann, K., and Ghoddoussi, A., “Correlating Engineering Statics Student Performance with Scores of a Test over Pre-requisite Material Involving Problem Solving”, Proceedings of the 2014 Midwest Section Conference of the American Society for Engineering Education, 2014

Rezaei, A., “Lessons Learned from a Newly Developed Hybrid Vector Statics Course Based on Fundamental Concepts and Hands on Experiments”, Proceedings of the 2007 American Society for Engineering Education Pacific Southwest Annual Conference Copyright, 2007

Rutz, E. , Eckart, R., Wade, J., Maltbie, C., Rafter, C., Elkins, V., “Student Performance and Acceptance of Instructional Technology: Comparing Technology-Enhanced and Traditional Instruction for a Course in Statics”, Journal of Engineering Education, Vol. 92, n. 2, p. 133–140, 2003

Halloun, I., and Hestenes, D., “Common Sense Concepts About Motion”, American Journal of Physics, Vol. 53, p. 1056–1065, November 1985

Hestenes, D., Wells, M., and Swackhamer, G., “Force Concept Inventory”, The Physics Teacher, Vol. 30, p. 141–158, 1992

Steif, P. S., “An Articulation of the Concepts and Skills Which Underlie Engineering Statics”, 34th Annual Frontiers in Education, 2004

Bernhold, L., Spurlin, J.E., and Anson, C., “Understanding our Students: A Longitudinal-Study of Success and Failure in Engineering With Implications for Increased Retention”, Journal of Engineering Education 96(3). pp 263-274, 2007

Takahira, S., Goodings, D. J., and Byrnes, J. P., “Retention and Performance of Male and Female Engineering Students: An Examination of Academic and Environmental Variables”, Journal of Engineering Education 87(3), 297–304, July 1998

Rohrbeck, C.A., Ginsburg-Block, M., Fantuzzo, J.W., and Miller, T.R., “Peer-Assisted Learning Interventions With Elementary School Students: A Meta-Analytic Review”, Journal of Educational Psychology, 95(2). pp 240-257, 2003

Dym, C.L., Wesner, J.W., Winner, L., “Social Dimensions of Engineering Design: Observations from Mudd Design Workshop III”, Journal of Engineering Education, 92(1). pp 105-107, 2003

Accreditation Board for Engineering and Technology, Criteria for Accrediting Engineering Programs. Retrieved from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017

Dym, C.L., “Representing Designed Artifacts: The Languages of Engineering Design”, Archives of Computational Methods in Engineering, Vol.1 (1). pp 75-108, March 1994

Mabogunje, A., and Leifer, L.J., “Noun Phrases as Surrogates for Measuring Early Phases of the Mechanical Design Process”, Proceedings of the 9th International Conference on Design, Theory and Methodology, American Society of Mechanical Engineers, 1997

Obenland, C.A., Munson, A.H., and Hutchinson, J.S., “Silent and vocal students in a large active learning chemistry classroom: Comparison of performance and motivational factors”, Chemistry Education Research and Practice, 14. (1) pp 73-80, 2013

Avsec, S., and Kocijanic, S., “A Path Model of Effective Technology-Intensive Inquiry-Based Learning”,Educational Technology & Society, Vol.19(1), pp.308-320, 2016

Hannafin, M. J., and Land, S. M., "Technology and student-centered learning in higher education: Issues and practices", Journal of Computing in Higher Education, 12(1), 3–30. April 2012

Kim, M. C., and Hannafin, M. J.,"Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice", Computers & Education, Vol. 56 (2), pp.403–417, February 2011

Jonassen, D. H., "Toward a design theory of problem solving", Educational Technology Research and Development, Vol. 48(4), pp.63–85, December 2000

Mayer, R. E., and Wittrock, M. C., "Problem solving", P. A. Alexander, & P. H. Winne Eds. Handbook of educational psychology (2nd ed.). , pp. 287–304, New York: Macmillan. 2006

Scardamalia, M., and Bereiter, C., "A Brief History of Knowledge Building", Canadian Journal of Learning & Technology, Vol. *36*(1), pp.1-16, 2010

Haughton, N. "Proposing a competency-based model that connects micro- and macro-level assessment", Proceedings of the at 42nd International Conference on Improving University Teaching, 2017, Tel Aviv, Israel, 2017

Bloom, B.S., and Krathwohl, D.R., "Taxonomy of educational objectives; educational goals by a committee of colleges and university examiners", Handbook I: Cognitive Domain. New York, NY; Longmans, Green. 1956

Voorhees, R. A., "Competency-Based Learning Models: A Necessary Future", In R. A. Voorhees (Ed.). New Directions for Institutional Research: No 110. Measuring what matters: Competency-based learning models in higher education (pp. 5-13). San Francisco: Jossey-Bass, Summer 2001

Rothwell, W.J., and Gaber, J. M., "Competency-Based Training", Alexandria, VA: American Society for Training and Development, 2011

ESG, "Standards and guidelines for quality assurance in the European Higher Education Area", Retrieved February 26, 2019 from https://enqa.eu/wp-content/uploads/2015/11/ESG_2015.pdf, 2015

Lumina Foundation, "The Degree Qualifications Profile: A learning-centered framework for what college students should know and be able to do to earn the associate, bachelor's or master's degree", Retrieved February 26, 2019 from http://degreeprofile.org/press_four/wp-content/uploads/2014/09/DQP-web-download.pdf., 2014

Black, P.J., and William, D., "Developing the theory of formative assessment", Educational Assessment Evaluation and Accountability, Vol. 21(1). pp 5-31, February 2009

Hiebert, J., Carpenter, T.P., Fennema, E., Fuson, K., Human, P., Murray, H., Olivier, A., and Wearne, D., "Problem Solving as a Basis for Reform in Curriculum and Instruction: The Case of Mathematics", Educational Researcher, 25(4). pp 12-21, May 1996

Boaler, J., "Open and Closed Mathematics: Student Experiences and Understandings", Journal for Research in Mathematics Education, Vol. 29(1). pp 41-62, 1998

Dillon, J.T., "The Classification of Research Questions", Review of Educational Research, Vol. 54. pp 327-361, Fall 1984

Ames, C., "Classrooms: Goals, Structures, and Student Motivation", Journal of Educational Psychology, Vol. 84(3). pp 261-271, 1992

Slavin, R.E., Hurley, E.A., and Chamberlain, A., "Cooperative Learning and Achievement: Theory and Research", In Handbook of Psychology (pp 177-198). Hoboken, NJ: Wiley, 2003

Webb, N.M., "Task-Related Verbal Interaction and Mathematics Learning in Small Groups", Journal for Research in Mathematics Education, Vol. 22(5). pp 366-389, November 1991

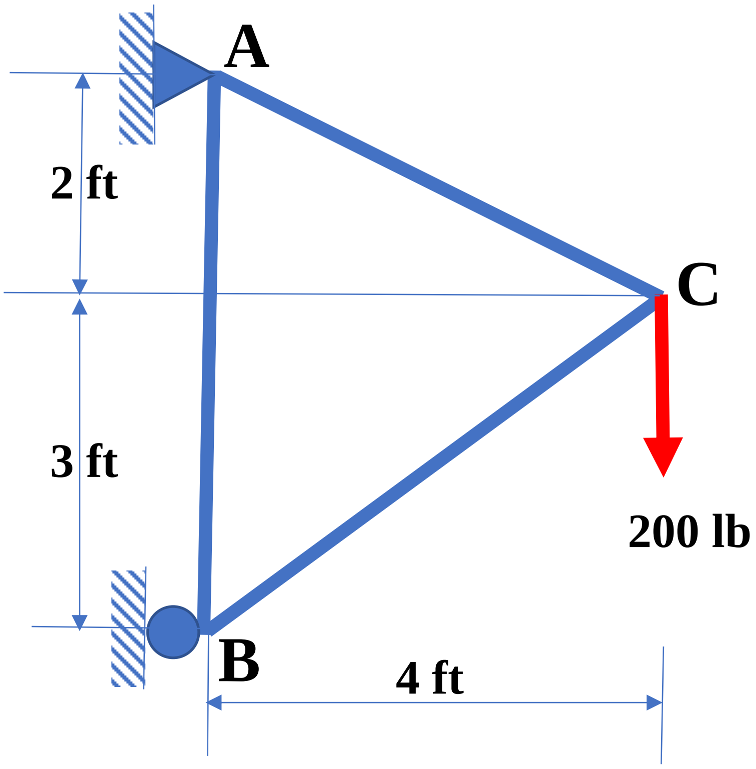
Taras, M., "Assessment - Summative and Formative - Some Theoretical Reflections", British Journal of Educational Studies Vol. 53(4). pp 466-478, November 2005

Linn, R.L., Baker, E.L., and Dunbar, S.B., "Complex, Performance-Based Assessment: Expectations and Validation Criteria", Educational Researcher, 20(8). pp 15-21, November 1991

Wankat, P.C., Felder, R.M., Smith, K.A., Oreovicz, F.S., "The Scholarship of Teaching and Learning in Engineering", Chapter 11 of M.T.Huber and S.Morreale, eds., Disciplinary Styles in the Scholarship of Teaching and Learning: Exploring Common Ground (pp 217-238). Washington: AAHE, 2002

Appendix 1: Worksheet Examples

Problem # 1



Using a force meter, the following forces were measured for the truss above, subject of 2 external forces:

- in 2 supports: ***160lb, 200lb, 160lb***
- in 3 members: ***120lb (T), 179lb (T), 200lb (C)***

Assign these force values to each support and member so that the structure is in equilibrium.

List the issues and / or the discussions that you and your group had when solving this problem.

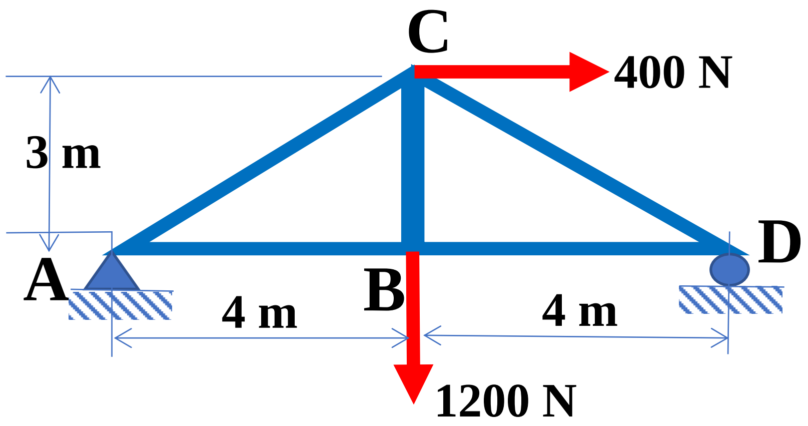
a) ____

b) ____

c) ____

d) ____

Problem # 2



R_{Ax} = _________N

R_{Ay} = _________N

R_D = _________N

F_{AB} = _________N

F_{AC} = _________N

F_{DB} = _________N

F_{BC} = _________N

F_{DC} = _________N

Reaction forces in supports:

Joint A

Joint B

Joint C or D

List the issues and / or the discussions that you and your group had when solving this problem.

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________