TO TEACH IS TO LEARN: STUDENT AND INSTRUCTOR PERSPECTIVES ON ASSIGNMENT DEVELOPMENT AS A SPRINGBOARD TO DEEP LEARNING

MV Jamieson mvjamies@ualberta.ca, L Goettler goettler@ualberta.ca, A Liu aliu1@ualberta.ca, JM Shaw jmshaw@ualberta.ca,

Department of Chemical and Materials Engineering, Faculty of Engineering, University of Alberta

ABSTRACT

Of the three levels of learning – surface, strategic, and deep (Bain, 2004) – the traditional lecture style combined with large class sizes often found in engineering and science programs tends to encourage surface learning. Students may not progress to, or past strategic learning because the motivation to understand concepts beyond attaining a desired grade can be limited. The Canadian Engineering Accreditation Board (CEAB) Graduate Attribute performance criteria target deep learning with the demonstration of synthesis and evaluation of concepts. Engineering graduates should be able to create and evaluate innovative solutions for a sustainable world. During an eight-month co-op work term, two of the authors were employed to develop instructional materials for an introductory chemical engineering design course. Our goals were to develop design lab assignments to support deep learning; target Bloom's higher level cognitive and affective domain skills; support contextual knowledge experience, and achieve progress in all CEAB graduate attributes. Through this experience, the co-op students gained a deeper level of understanding of the materials than achieved after completion of the course for credit. This paper explores their experience; the instructors' experience; the structure of their work; and the method of assignment design, development, and testing. Engineering instructors *can* encourage and abet deep learning of course materials by incorporating opportunities for peer teaching, peer editing interactions, and relevant assignment development experiences. Illustrative design course examples, and our reflections on outcomes are presented and discussed.

KEYWORDS

Peer Teaching, Deep Learning, Design, Integrated Learning, Active Learning, Collaborative Learning, Faculty Development, Action Research, CDIO Standards: 1, 2, 3, 5, 7, 8, 9, 10, 11

INTRODUCTION

The expectation that learners are required to teach has the potential to transform how we learn (Nestojko, 2014). Peer teaching and evaluation were employed as a structured method to format the work of co-op students hired to develop learning materials for a chemical engineering process design course. Two students were hired for a four-month work term and two were hired for an eight-month work term. All four co-op students contributed to assignment and quiz design for four months and had previously completed the introductory undergraduate design course. The two students completing eight-month work terms provided peer teaching in the design lab as undergraduate lab assistants and reflected on their own learning as they continued to develop assignments. These students also researched learning methods, reflected on their experience, and presented their findings at a conference. The process followed was to conceive, design, implement, and operate in the context of Process Design lab assignments. This paper reports on the peer student teaching/mentoring experiences (students transformed into teachers) and the instructors experience in guiding them. The benefits of employing peer teaching and mentoring for course instructors, student mentors, and undergraduate students taking the design course are presented and discussed.

LITERATURE REVIEW

Deep learning (Bain, 2004) opportunities and the expectation of using learned material in an anticipated teaching activity (Nestojko, 2014) support skill development. The expectation of performance is also linked to learning and motivation (Biggs, 1999, 2003; Biggs and Tang, 2011). Learning is meaning centered and constructed in context and often motivated by the context (Resnick and Klopfer, 1989). Collaborative Learning techniques have been used in multiple contexts (Heller, 1992) to promote student achievement. Hattie (Hattie, 2009) reports the highest ranked factors for teaching or teacher related effects are: formative feedback to *teachers* (d=.90), teacher clarity (.75), **reciprocal teaching** (.74), feedback (.73), spaced vs. mass practice (.71), **metacognitive strategies** (.69), self-verbalization/self questioning (.64), professional development (.62) and **cooperative vs. individualistic learning** (.59). Reciprocal teaching is an activity where teachers and students *share* the role of teaching. By comparison the highest ranked factors for students are: self-reported grades (1.44); **concentration**, **persistence,** and **engagement** (.48); and gender (.12). This suggests that choices made by instructors have a greater impact on student achievement than student empowerment. Group work and collaboration further encourage metacognition as students solve problems (Metcalf, 2008) and *reflect* on their learning (Bain, 2012). Student choices and decisions impact their learning outcomes, while instructor choices impact students' participation in the higher impact activities. Some students develop a deep transformative learning orientation by turning failure into opportunities and **using reflection** to navigate murky situations (Bain, 2012). This learning orientation, coupled with instructor created opportunities for student teams to engage in self-directed outcome-oriented learning leads to meaningful mentorship opportunities, fosters deep learning, and provides an empowering environment for student achievement and life-long-learning skill development. By engaging with the co-op students in course preparation and delivery, the instructors expected to lever the learning effects bolded above, in particular, to move the co-op students working with us and students taking the course for the first time from surface or strategic learning toward deep learning as a life long practice. Action research, (Carr and Kemmis, 1986; Kember, 2000; Kemmis and McTaggart, 1988; Case and Light, 2011) a methodology where research is done *with* subjects and not *on* them, is described as "taking place within everyday, natural contexts rather than controlled settings" (Cousin, 2009). The aims and benefits of action research are the strategic improvement of practice (Case and Light, 2011). Often utilizing a continuous cycle of four movements: a plan of action for improvement, action to implement the plan, observation of the effects in context, and reflection on these effects as the basis for future improvements and planning (Kemmis and McTaggart, 1988), action research is similar to the conceive, design, implement, operate process. The metacognitive strategy of reflection on in-context observations coupled with implementation and operation experience influences the achievement of deep learning.

METHOD

We used a case study methodology to follow the assignment development progress. The co-op students and instructors reflected on their personal observations and learning as the conceive-design-implement-and-operate process unfolded. The situative learning framework defines knowledge "as distributed among people and their environments, including objects, artifacts, tools, books, and the communities of which they are a part" (Greeno, Collins & Resnick, 1996). Learning is seen as meaningful participation in a community of practice (CoP) (Johri and Olds, 2011). The case study approach in a CoP context was intended to draw out the learning of the team, and to examine the deeper issues in the experience described by Johri and Olds in a structured manner that includes action research and grounded theory. "Action research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practice, their understanding of these practices, and the situations in which the practices are carried out" (Carr & Kemmis, 1986). Action research methodology was used to classify experiences qualitatively and to make comparisons with accepted learning frameworks (Greeno, Collins & Resnick, 1996). We respected the dialectical nature (Case and Light, 2011) of the active research methodology.

The research questions we address are: Did the experience of preparing, implementing, adapting, and reflecting on course materials impact the nature of the learning (surface, strategic, deep) of the two peer instructor co-op students? Did the peer instructors abet the learning of the students taking the course for the first time? A peer work structure was conceived, designed, implemented, and then operated. The end objective of creating learning activities aligned with learning objectives, mapped to the CEAB graduate attributes, was specified and the process allowed to proceed organically. Work reports, reflections and discussions were reviewed for common threads and viewpoints, as well as differing perspectives. Summative qualitative reflections are included among the results. The case study was completed from an experiential viewpoint as the research questions were asked and answers obtained from our work team. Feedback from students to the peer instructors directly, and instructor observations also informed our reflections.

Peer Work Structure – Developing Quizzes and Assignments

The four co-op students on the work team previously completed design lab assignments for credit and indicated a high degree of motivation to work with minimal supervision in a team setting. The initial assignment development tasks were performed by pairs of students and based on previously completed assignments. Additional quiz questions were developed individually and tested by the paired students who gave feedback leading to a first revision. The revised questions were tested by one of the students working in the other pair and the feedback revision process was repeated. Last, a fourth student tested the second revision and gave further feedback. Both pairs of students were given assignment development tasks with the expectation that the other pair would test the questions. This structure was maintained when the work progressed to developing new assignments. One pair of students designed assignment questions for an ethane + propane cracker and the other pair for a sulphur plant. None of students had prior experience with either chemical process. The assignments were further revised ahead of implementation (Fa16, and Wi17) by the instructors and the co-op students engaged in peer mentoring (Fa16).

Training Provided

The four co-op students attended teaching workshops provided by the University of Alberta Center for Teaching and Learning (CTL) including one by Ken Bain. The pre-reading required for this workshop was "What the Best College Teachers Do" (Bain, 2004). The students had the opportunity to learn effective methods (Hattie, 2009) for enhancing student achievement. The focus was on what an instructor could do. These methods were discussed along with their experiences and ideas at bi-weekly meetings and more frequently as the work transitioned from development to classroom implementation. The work term students were invited to consider the engineering education research aspects of the process and to investigate and apply education research to their work. They were invited to consider the possibility of developing research contributions based on their assignment development and peer teaching experiences in collaboration with the instructors!

Design Course Context

Chemical Engineering Design I is a 13-week course taken in the seventh semester of the chemical engineering undergraduate program. The course covers "engineering design concepts; cost estimation; project planning and scheduling; plant safety and hazards analysis; selected project design examples" (University of Alberta Course Catalogue, 2013). Eight weeks are spent in a lecture format with weekly lab assignments. Five weeks are dedicated to work on introductory-level design projects. The class is divided into groups of three or four students at the beginning of the course, and these groups work together on lab assignments and design projects. Lab assignments concern engineering design topics and are due weekly. The first assignment, an introduction to the course and to design analysis, and the last assignment, on the use of an advanced steady-state process simulator (VMGsim) are fixed. Six other assignments vary in detail from term to term and address: flowsheets; fluid movers; heat exchangers; reactors; separation vessels; and costing and economics. From a teaching methodology perspective, the course can be described as employing a cognitive framework (Greeno, Collins, and Resnick, 1996) for the lab assignments and it then introduces a situative framework for the design project. The situative framework is also employed in the follow up Capstone Process Design course. The attributes of these comparative frameworks were tabulated by Johri and Olds, and are rehearsed here as Table 1.

RESULTS AND DISCUSSION

Overview

The co-op students first explored the generation gap between instructors and students in courses and researched how to bridge the gap. They presented their reflections on the development of the internet and the impact it has had on the way instructors and students interact with information, learn, and how to bring the classroom forward into the 21st century at the 2016 CSChE Conference Chemical Engineering Education Symposium as "Improving the Learning Experience for Millennials, by Millennials". The peer teaching students also presented a preliminary version of the present contribution as "To Teach is to Learn" at the same conference and won second place in the Reg Friesen competition (Figure1). More importantly, the peer mentor students and instructors classified their collective experience as a deep learning experience – the students were motivated to learn more than they had learned while taking the introductory design course for credit, and continued learning about design and teaching. Mentoring and teaching their peers in the classroom was rewarding for them and for the students they mentored. Their peer-mentor role complimented the more

Table 1. Learning Frameworks Comparison (Johri and Olds, 2011)

Framework	**Behaviorist**	**Cognitive**	**Situative**
The Nature of Knowing	Knowing as having associations	Knowing as concepts and cognitive abilities	Knowing as distributed in the world
The Nature of Learning Transfer	Acquiring and applying associations	Applying and using conceptual and cognitive structures	Becoming attuned to affordances and constraints through participation
The Nature of Motivation and Engagement	Extrinsic motivation	Intrinsic motivation	Engaged participation
Guidelines for Design of Learning Environments	*Routines of activity for effective transmission of knowledge *Clear goals feedback and reinforcement *Individualization with technologies	*Interactive environments for construction of understanding	*Environments of participation in social practices of inquiry and learning *Support of development of positive epistemic identities
Guidelines for Curricular Design	*Sequences of component to composite skills	*Sequences of conceptual development *Explicit attention to generality	*Development of disciplinary practices of discourse and representation *Practices of formulating and solving realistic problems
Guidelines for Assessment Design	*Assessment of knowledge components	*Assessment of extended performance *Crediting varieties of excellence	*Assessing participation in inquiry and social practices of learning *Student participation in assessment *Design of assessment systems

formal instructor-student interaction and facilitated learning. All four co-op students were motivated to develop assignments that were targeted to achieve the course learning objectives while minimizing workload. They had the experience of completing their seventh of eight academic terms and had first-hand design experience to draw on. They understood the course objectives, the context of the CEAB graduate attributes, and had gained experience teaching each other prior to their opportunity to become peer mentors. The preparation of the assignments with the expectation they would teach further motivated the peer mentor students to ensure that they understood how to explain the questions and concepts to students taking the course for credit. The students taking the course for credit asked instructors and peer mentors for guidance. The peer mentors asked one another and the instructors guidance. The peer mentors provided a viewpoint that the work was possible and that undergraduate students could achieve higher cognitive task levels in the design lab assignments that they helped design and test. Peer mentors were not used in the previous or following offerings of the course and instructors were much busier during design labs with questions even though teaching assistants were available. Students taking the course for credit actively sought the advice and assistance of the peer mentors, underscoring the credibility of their contributions. The majority of the students in the class was also keen to support the peer mentors and completed voluntary consent forms so that photos including them and the peer mentors could be used for publication.

Figure 1. Second Place in the Reg Friesen Competition

Co-op Student Peer Instructor Reflections

<u>Peer instructor #1</u>: At the start of the work term, I was skeptical about what I would be able to obtain from this job. I saw field engineering work as superior because I would see how people and equipment work at a fundamental physical level. I saw office engineering work as superior because I could see how corporate workers collaborate to design and carry out technical projects. I felt working for the University of Alberta as a course development assistant wasn't the best choice for my last work term, as I would only be obtaining more theoretical knowledge. I was both right and wrong. I was right that I would be mostly obtaining more theoretical knowledge. I was wrong thinking that this was an inferior job opportunity because I acquired a lot more theoretical knowledge than I was expecting and *the knowledge I acquired was at a much deeper level than what I obtained from my courses*. Overall I feel more confident to tackle industrial problems now.

So why did I acquire a deeper level of understanding through my work term than through my courses? Because I was motivated to develop a deep understanding for the material rather than just understand it enough to get a good grade. I had been a strategic learner, I learned as much as I needed to in order to do well on the exams - nothing more, nothing less. I had nothing motivating me other than getting a good grade and I was already getting a good grade. When in school, there is so much material being bombarded at me that even for material that I'm interested in, I don't have time to think about it and digest it. There is a constant need to move on to the next assignment or to the next course to study. Coupled with the likelihood that the vast majority of what we learn in school we will never see again and knowing a lot of the required learning will happen at the workplace, there just isn't much motivation to understand the material besides getting good grades and hoping that means companies are more likely to hire me. Then there is the boring format that most lectures go through where the instructors just go up there and talk and there's virtually no connection between students and instructors other than the occasional question. Boring lecture format and a lot of boring material is a mixture that gives zero reason to learn any material. It was easy to get away with having gaps in my understanding and a superficial level of understanding during the design course as a student because the bulk of the course work was done in teams. I was fortunate enough to be in a group with highly competent team members and if I didn't understand something, at least one of them did. So instead of learning about what I didn't understand, I delegated the work in those areas to my team in order to save everyone time. When I was done the course, I got a lot better in areas that I was already competent in but my areas of weakness stayed where they were. This in part was reflected on the final exam for the course, I had no problems with questions on sections that I was familiar with such as equipment sizing and costing. But on the questions testing material that my group members took care of such as the theoretical design concepts behind equipment selection and how each piece of equipment worked, I struggled.

So how did my work this co-op term help me progress beyond strategic learning and into deep learning? The modules and assignments for the introductory design course are each based on certain pieces of equipment and certain design concepts. Without a solid fundamental understanding of these concepts and how equipment works, it is impossible to develop questions and to teach students the material. So if I didn't actually understand the material, I essentially couldn't do what I was getting paid to do.

Figure 2. Motivation: Responsibility for other students' learning

Being able to do my work and appearing competent is one motivator, but the major motivating factor for fully understanding the material was the *responsibility for other students' learning.* (Figure 2.) While in school, if I didn't understand something, the only one that I was hurting was myself. As part of the instructional team, if I don't understand something or if I have the wrong understanding of a concept, not only do I look foolish when the students ask me questions and I don't know the answers or give them the wrong answer, but also the students may also not learn the material or learn it wrong. I interacted with these students for 6 hours a week in person and through email so the impact I had on these students was significant. The course started with over 100 students, so the impact of my inadequate understanding would be 100 fold. These 100+ students then have their own social circles which I would have an indirect impact on. Imagine if one of these students ended up working for a big plant some years down the road and because I taught them something wrong, they ended up blowing up a plant. That responsibility is on me. That situation may be a bit of a stretch but I was absolutely not willing to let my own incompetence become the problem of 100+ students.

This concept of learning through teaching is nothing new. There have been numerous studies on the subject and some of the studies suggest that this is the very reason why the eldest sibling is the most intelligent in most cases (Kristensen, 2007). Some of the sources that support this idea and that we used for our presentation at the CSChE are included in the references.

Peer instructor 2: I collaborated in the development of an assignment set based on an ethane-propane cracker. It would be impossible to write assignments and accompanying solutions for material I was not certain about, and as such, it was necessary to be blatantly honest with myself as to which concepts I had not thoroughly learned previously. This was an interesting change of perspective, as I now took my learning of the material more seriously than when I had been going through the course myself. This time, not only was someone relying on me to perform accurate work, without the safety blanket of being an 'introductory design student', but others were relying on me to teach them these concepts accurately and quickly. The most obvious outcome of this was that my knowledge upon completion of my co-op term now greatly surpasses that of when I completed the introductory design course, and I am now much better at communicating ideas to classmates. While going through my academic career, and especially while I was an undergraduate lab assistant, I found there was an optimum point of communication – too little and the student does not have the full picture, but too much and the learning objective becomes confused. I focused on conveying the information to the student as completely, but as effectively and quickly, as possible.

To ensure maximum student learning without repetition or extraneous work, it is necessary to identify whether the information the students interact with in lecture is either primary design knowledge (knowledge gained in prior university courses or high school) or secondary design knowledge (new information learned in CHE 464, co-requisites, or professional experience). This categorization directly affects how the information is presented and how it is tested in the assignment set. By categorizing the level of understanding, it is possible to understand how to develop students' critical thinking skills to the 'creation' level, based on the revised Bloom's Taxonomy shown in Figure 3. Secondary knowledge must be taught gradually with more guidance to ensure that the students develop a proper conceptual framework. When primary knowledge is expanded upon, the students' conceptual framework must first be addressed to ensure no misinformation, and then concept difficulty can increase quickly. One of the defining features of CHE 464 is the clear contextualization and real-life application of the processes and equipment examined. In every assignment and most of the lecture notes, students are asked to consider the equipment beyond simply sizing or costing. These considerations include: type of equipment used; safety and environmental risks and management methods; metallurgy and types of material concerns; equipment arrangement and location; accommodation for catalyst deactivation; and rationalization of compressor surge and process flare lines. None of these topics are discussed in course prerequisites but are at least as important as the sizing and costing of the equipment.

Instructor Reflections

Instructor 1: Initially my goals were to support the Faculty of Engineering co-op student employment program and diversify the question bank for the design lab assignments. It seemed like a good match. I was willing to invest some time. I knew other professors had successfully employed students to help develop assignments and I had been developing assignments myself for the design courses and collaborating with my teaching partners. I understood the value of having someone who had just learned or was still learning the material to help tune an assignment set to the abilities of the target student cohort. I planned to set up their work environment with peer accountability, flexibility, and self-management as characteristics of their work team. My management style is to hire talented people, give them training, a process, resources, my support, confidence, and expect them to deliver the product. I was reading Ken Bain's book and knew he was presenting at the Summer CTL session.

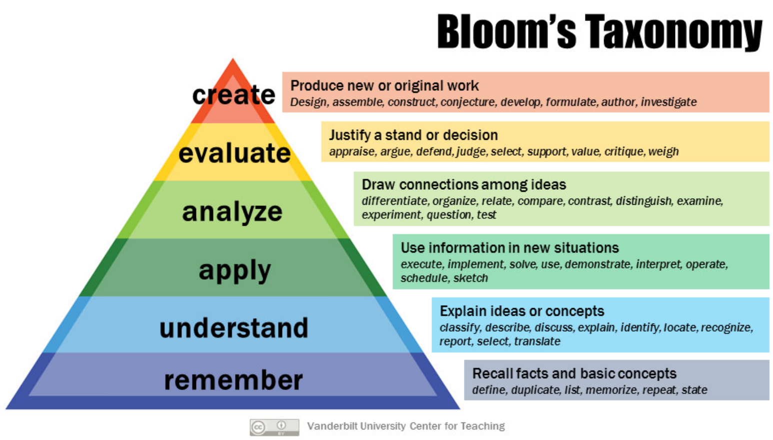

Figure 3. Bloom's Taxonomy (Modified version 2012) (Armstrong, 2016)

I decided to invite the co-op students to the session and have them take notes for me at the sessions I wasn't attending. I soon realized that they were very interested in making a difference and I gave them some opportunities to research teaching and learning and suggested that they might be able to present their work at a conference in the fall. They became very interested in developing their work from an academic perspective. Their desire to make a difference was clear. I also suggested that they would be helping in the design lab with the assignments they were developing (Figure 4). I could see their engagement developing as we interacted. Their ideas, knowledge, analysis, evaluation, and creative skills developed. At first they just copied the questions and changed the context. Then they began to develop skills to write better questions, to classify the questions with Bloom's Taxonomy and critique the questions with respect to the learning objectives. They began to learn about generational traits, Internet development and the relationship to the traits, Bloom's Taxonomy, learning objectives, and Bain's levels of learning. By the end of the work term they were able to identify knowledge gaps and where leaps were being made that undergraduate design students found difficult to make with us. The two students who worked on the project for four months volunteered to come help in the lab to have the operate part of the design experience. For me this was an innovative and collaborative experience that enhanced my perspective of teaching and learning. It demonstrated to me how students could be empowered to develop a deep transformative learning environment. It emphasized the importance of the situation and intrinsic motivation in creating a meaningful contextual learning environment where students can construct their learning activities. As a result I am encouraged to include more peer teaching and mentoring activities explicitly in the course. Since design students are typically young adults with developing experience, the shift from a behaviorist to cognitive framework encourages the shift from extrinsic to intrinsic motivation for learning. In this case, the motivational shift to "engaged participation" appears to have been accomplished by the expectancy of meaningful contribution in a stituative context (Greeno, Collins, and Resnick, 1996) and appears to have been causal in students shifting to a deep learning paradigm.

Instructor 2: When we embarked on this project, I knew we would obtain useful and flexible assignment and quiz question banks for the design course. I had not expected to learn so much, first hand, about how excellent and motivated undergraduate students view courses and their own course performance. I had also not appreciated the significance of the impacts of strategic task management within student teams on the perpetuation of technical knowledge deficits and hence on CEAB graduate attribute attainment. This heightens my desire to create environments and to motivate more students to move from strategic to deep learning as we further develop the curricula for both the introductory and capstone design courses.

Figure 4. Operate – Teaching in the design lab

CONCLUSIONS

Through collaborative development and implementation of engineering design lab assignments intended to be meaningful and constructively aligned learning experiences for undergraduate students taking the design course for credit, both instructors and peer mentors were able to reflect on how to assist chemical engineering graduates to become deep and life long learners. The process used to design the assignments essentially followed the conceive-design-implement-operate model and the peer teaching students were able to follow the process to the operate stage, reflect on the results, and make recommendations for improvement. Peer teaching and mentorship were used to promote both deep and life-long learning. The operate stage clearly had an impact on the learning and motivation of the peer mentors. By taking responsibility for the understanding of others, they were motivated to deepen their own knowledge. Students can create deep learning experiences when supported with a learning environment and a process that require them to design and perform meaningful contextual work including disciplinary practices of discourse and social practices of inquiry like teaching and mentoring peers.

Acknowledgements

Financial support from the Faculty of Engineering and the sponsors of the NSERC Industrial Research Chair in Petroleum Thermodynamics (Alberta Innovates - Energy and Environment Solutions, BP Canada Energy Corporation, ConocoPhillips Canada Resource Corporation, Natural Sciences and Engineering Research Council of Canada (NSERC), Nexen Energy ULC, Shell Canada, Total E & P Canada, Virtual Materials Group Incorporated) is gratefully acknowledged.

REFERENCES

Armstrong, P. (2016). "Bloom's Taxonomy." Vanderbilt University, Center for Teaching. Bloom's Taxonomy. https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

Bain, K. (2004). *What the best college teachers do.* Cambridge, Mass.: Harvard University Press.

Bain, K. (2012). What the best college students do. Cambridge, Mass.: Belknap of Harvard University Press.

Bloom, B., Englehart, M., Furst, E., Hill, W., & Krathwohl, D. (1956). Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook I: Cognitive Domain. In Anderson. L.W., Sosniak, L.A, (Eds.), (1994). Bloom's Taxonomy: A Forty Year Retrospective. The National Society For the Study of Education: Chicago, 200 pp.{ISBN: 978-0077-5762}

Biggs, J.B. (1999). "What the Student Does: teaching for enhanced learning". Higher Education Research and Development, 18(1), 57-75.

Biggs, J. B. (2003). Teaching for Quality Learning at University: What the Student Does. Buckingham; Philadelphia, PA: Society for Research into Higher Education : Open University Press.

Biggs, J. B., Tang, C. S., & Society for Research into Higher Education (2011). Teaching for Quality Learning at University: What the Student Does. Maidenhead: McGraw-Hill Education.

Campbell, L., and B. Campbell. (2009). "Beginning With What Students Know - The Role of Prior Knowledge in Learning." In Mindful Learning 101: Proven Strategies for Student and Teacher Success, 7-21. Thousand Oaks: Corwin Press.

Committee on Developments in the Science of Learning with additional material from the Committee on Learning Research and Educational Practice. (2000). Board on Behavioral, Cognitive, and Sensory Sciences; Division of Behavioral and Social Sciences and Education; National Research Council, *How People Learn: Brain, Mind, Experience, and School: Expanded Edition,* National Academy Press.

Carr, W., & Kemmis, S. (1986). *Becoming critical: Education, knowledge, and action research*. London, UK: Routledge.

Case, J.M., and Light, G. (2011) "Emerging methodologies in engineering education research," Journal of Engineering Education 100 (1) pp.186-210.
Cousin, G., (2009) *Researching learning in higher education: An introduction to contemporary methods and approaches*. p.150, New York, NY: Routledge.

Greeno, J., Collins, A., & Resnick, L. (1996). Cognition and Learning. In R. Calfee & D. Berliner (Eds.), Handbook of educational psychology (pp. 15–46). New York, NY: MacMillan.

Hattie, J. (2009). The Black Box of Tertiary assessment: an impending revolution. In L. H. Meyer, S. Davidson, H. Anderson, R. Fletcher, P.M. Johnston, & M. Rees (Eds.), Tertiary Assessment & Higher Education Student Outcomes: Policy, Practice & Research (pp.259-275). Wellington, New Zealand: Ako Aotearoa

Heller, P., Keith, R., and Anderson, S. (1992). “Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving,” Am. J. Phys. 60, pp. 627–636.

Heller, P., and Hollabaugh, M. (1992). “Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups,” Am. J. Phys. 60, pp. 637-644.

Jamieson, M.V. (2016). “Application of Blended and Active Learning to Chemical Engineering Design Instruction”, University of Alberta

Johri, A., & Olds, B. M. (2011). “Situated engineering learning: Bridging engineering education research and the learning sciences”. Journal of Engineering Education, 100(1), 151–185.

Kember, D. (2000). Action learning and action research: Improving the quality of teaching and learning. London, UK: Routledge.

Kemmis, S., and McTaggart, R. (1988). The action research planner (3rd ed.). Geelong, Victoria, Australia: Deakin University Press.

Kristensen, P., Bjerkedal, T. (2007). Explaining the Relation Between Birth Order and Intelligence. Science (22 Jun 2007): Vol. 316, Issue 5832, pp. 1717 DOI: 10.1126/science.1141493

Metcalfe, J., & Finn, B. (2008). “Evidence that judgments of learning are causally related to study choice”. Psychonomic Bulletin & Review, 15, 174–179.

Nestojko, J.F., Bui, D.C., Kornell, N. et al. (2014). “Expecting to teach enhances learning and organization of knowledge in free recall of text passages”. Memory & Cognition (2014) 42: 1038. doi:10.3758/s13421-014-0416-z

Resnick, L., & Klopfer, L. (Eds.). (1989). Toward the Thinking Curriculum: Current Cognitive Research. Alexandria, VA: Association for Supervision and Curriculum Development.

BIOGRAPHICAL INFORMATION

Marnie V. Jamieson, M. Sc., P.Eng. is an Industrial Professor in Chemical Process Design In the Department of Chemical and Materials Engineering at the University of Alberta and holds a M.Sc. in Chemical Engineering Education. Her current research focuses on the application of blended and active learning to design teaching and learning, student assessment, and continuous course improvement techniques. She managed and was a key contributor to a two-year pilot project to introduce Blended Learning into Engineering Capstone Design Courses, and is a co-author with John M. Shaw on a number of recent journal, book, and conference contributions on engineering design education.

John M. Shaw PhD., P.Eng. is a Professor and NSERC Industrial Chair in Petroleum Thermodynamics in the Department of Chemical and Materials Engineering at the University of Alberta. He has used distance synchronous teaching/learning approaches since the 1990's to co-instruct graduate courses with colleagues and students at remote locations, and has been a member of the University of Alberta Provost's Digital Learning Committee since its inception. He won an undergraduate student-sponsored teaching/mentorship award in 2009 and led a two-year pilot project to introduce Blended Learning into Engineering Capstone Design Courses. He is a co-author with Marnie V. Jamieson on a number of recent journal, book, and conference contributions on engineering design education.

Albert Liu is an undergraduate Chemical Engineering co-op student in the last semester of his studies at the University of Alberta. Albert's past work experience includes material testing in Fort McMurray and Valleyview for ARA Engineering and project engineering for the Canadian Gypsum Company in Calgary. During his last 2 co-op work terms, he was a member of the course development team and contributed to "Improving the Learning Experience for Millennials, by Millennials" and the award winning "To Teach is to Learn" presented at the 66th Canadian Chemical Engineering Conference in Quebec City.

Leah Goettler is a fifth-year chemical engineering undergraduate at the University of Alberta. Her work term experience has included materials testing for highway construction with ARA Engineering, and proprietary materials engineering research and development for Packers Plus Energy Services. She joined the chemical engineering design course development team for her final co-op experience. This opportunity enriched her engineering skills and enabled her to mentor others and collaborate with industrial professionals in a variety of contexts. She also contributed to "Improving the Learning Experience for Millennials, by Millennials" and the award winning "To Teach is to Learn" presented at the 2016 CSChE Conference.

Corresponding author

Marnie V. Jamieson, M.Sc. P. Eng.
University of Alberta
9211 - 116 Street NW
Edmonton, Alberta, Canada, T6G 1H9
1-780-492-8442
mvjamies@ualberta.ca

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported License.