Applying home schooling lessons to engineering education

F. Edwards, T. Daniel, W. Hale, A. Hanson, E. Richardson

University of Arkansas/University of Arkansas/University of Arkansas/New Mexico State University/New Mexico State University

Abstract
There is mounting evidence that homeschooling provides a better education than traditional classroom education. A comparison of standardized tests results showed that on average 5,402 homeschooled students outperformed public schooled students by 30 to 37 percentile in all subjects. The Tennessee Dept of Education found that 2nd grade homeschooled children scored in the 93rd percentile as compared to public school students who scored in the 62nd percentile and similar results have been reported in other states. These results have been attributed to various factors including parental involvement, class size, flexibility, and self-directed learning.

In homeschooling, students are given some basic instruction and then sent off to learn the material on their own. Similarly, self-directed learning (SDL) requires that the student take ownership of their own learning. As is seen with exceptional students, nontraditional students, and graduate students, students who take ownership of their learning greatly outperform other students. Ownership of learning and self-directed learning are key components of lifelong learning, which the American Society of Civil Engineers professes to be critical for professional success. Yet, current engineering education methodologies focus little on SDL and student ownership of learning; instead, the focus seems to be on how the instructor can be more entertaining or engaging.

The authors suggest that shifting from faculty centered learning to SDL has the potential to improve information retention, and critical thinking skills among entry level engineers. There is evidence that students will learn more and will have the tools required for lifelong learning if we set up classes using self-directed learning methods and the students take ownership of their own learning.

Introduction
It seems that every generation feels that youth are not fulfilling their potential and are not working as well or as diligently as the older generation did when they were students. But, there is evidence that current students are graduating without fundamental problem solving skills that are key to engineering and they are not well prepared to teach themselves skills they will need to learn in their careers.

One area of education that is providing higher scores and a background in self directed learning (SDL) is homeschooling. Homeschooling is typically conducted without lectures, the Learning Director (vs lecturer) gives the student some basic instruction and then sends the student off to

learn the material on their own. The authors suggest that shifting from faculty centered learning to self directed learning (SDL) has the potential to improve information retention, and critical thinking skills among entry level engineers.

For the past two decades there has been a quiet revolution in teaching engineering that has been led by pioneers such as Felder and Brent[1], Felder and Spurlin[2], and Kolb.[3] The focus has been on identifying student learning styles and being cognizant of which learning styles are being addressed during the faculty student interactions. Out of this has grown a realization that there is still another piece of the educational paradigm that has shifted and needs to be reconsidered. The student has come to expect the faculty to TEACH them. There has been a rejection on the part of the students of ownership or responsibility for the learning process. The common complaint among faculty is that the students seem to retain less and their ability to perform critical thinking with the material they retain is greatly diminished compared to students 20 years ago.

This increased focus in the engineering educational system on learning styles has been paralleled by a growing phenomenon in the lower educational levels; home schooling. It is suggested that it might be profitable to look to the home school community when considering this conundrum. In the early 1980's, the general public had not heard of home schooling. Today home schooling is a widely used and growing educational alternative. There are approximately 1.23 million American children being taught at home, which exceeds the total public school enrollment for the state of New Jersey, the 10th largest student population in the nation.[4]

Most home schooled children are taught in a self directed learning environment. The student is given responsibility for learning material and is later tested on competency. The instructor, a parent/mentor, is available as a resource, but usually does not lecture in a class room environment. This scenario makes it clear that the student is responsible for the learning activity. It is critical to note that when these students take standardized exams, or enter the university system, they typically perform very well. One can not know, but one can speculate, that this is at least in part because the students have taken ownership of their own learning process.

Over the past two decades, home schooling has been growing rapidly and there is now sufficient data available to examine the impact of home schooling based on standardized testing scores. Rudner showed that home school achievement tends to improve the longer a child has been taught at home and this distinction is especially greater in the higher grades.[4] This seems to indicate that it is the SDL environment, not the selection of students that is improving the student's performance. The data indicates that the benefits of SDL are independent of ethnicity and gender. Ray collected data on 5,402 home school students from 1,657 families for the 1994-95 and 1995-96 academic years.[5] Nearly 6,000 surveys were sent to home school families using a variety of teaching sources and methods. This work showed that regardless of ethnicity, gender, socioeconomic status, parent education level, teacher certification, or the degree of government regulation, the academic achievement scores of home educated students significantly exceed those of public school students. The study demonstrated that home-schoolers out-performed their counterparts in the public schools by 30 to 37 percentile points in all subjects. In addition, eighth grade home-schoolers who were home-schooled two or more years scored higher than students who have been home-schooled one year or less. The new home-schoolers were scoring on the average in the 59th percentile compared to students home-

schooled for two or more years who scored between 86th and 92nd percentile. It was also demonstrated that ethnicity was not a factor with grades K-12, the composite student body scored, on average, in the 87th percentile. These statistics would indicate that the learning environment may be the critical factor in the performance of these students.

This shifting of ownership from the faculty member to the student is what is at the heart of SDL. In SDL, responsibility is shifted back to the student to place boundaries on the activity to accomplish the goals established by the faculty. Once the student or students have identified a pathway that will accomplish the established goals, the faculty becomes a resource to assist in accomplishing the goals. It is the students who are taking the journey. The students are no longer sitting and watching, they have defined a pathway to solve the problem, they are participating in the solution.

If assignments are written correctly, the students can be encouraged to work much higher on Bloom's Taxonomy of Learning. Instead of gathering knowledge, the students must analyze the goals, synthesize a pathway to a solution, and then proceed to evaluate the success of their proposed pathway.

The advent of personal computers, societal changes, and continued evolution toward the efficient business model has fostered the need and acceptance of SDL. For example, fewer life-long company employees exist, resulting in large retraining needs in the adult-education area alone. Cross estimated that 70% of adult learning is self-directed. In the past several years SDL has been one of highest interest topics in adult education and education in general.[6] Knowles stated that SDL is not an educational fad, but a 'basic human competence-the ability to learn on one's own.''[7] So why the interest in SDL and what are the advantages? Piskurich lists several advantages, including availability when the training is needed, nonreliance on instructors, on-site implementation, trainee readiness, individualization, and consistency of presentation.[8] Gibbons was somewhat more holistic about the advantages of SDL in his classic "Walkabout" article where parallels are drawn between characters in the movie and advantages of SDL.[9] The crux of the movie finds two urban children abandoned in the Australian outback, lost, exhausted, and ill equipped to survive. By contrast, they are helped by a young aborigine undergoing his walkabout, an endurance test of surviving alone in the wilderness to return to his tribe an adult or die. Stark contrasts are drawn between the aborigine's readiness for the walkabout and the test of adolescent's readiness for adulthood in our own society. According to the author, students today face exams that test skills far removed from the actual experience required in real life. He writes, they solve familiar problems, do not apply what is known to strange but real situations and are under supervision in a protected environment and not allowed into the world to demonstrate their ability to survive and contribute to society. According to Confessore and Confessore SDL can be tied to an employee's   performance and incorporated into self-managed work teams, allowing team members to determine their learning and information needed to complete the task.[10] While, Durr[11], a Motorola training manager, takes a longer view by noting that the success of SDL at his company has been very valuable toward moving each employee toward 'becoming an empowered lifelong learner'. [12]

Self-Directed Learning
Dewey stated, 'The most important attitude that can be formed is that of the desire to go on learning'. Montessori compared the freedom or independence of self directed learning to breaking the bonds of servitude.[13]

It has been proposed that SDL is based on seven pillars: a project-oriented pedagogy, a contractual arrangement, a mechanism for induction and pre-training, new roles for trainers, an open training resources environment, an alternating pace, and a triple level of follow-up.

According to Knowles, the following are the skills required for a learner to become involved in a self-directed learning project.[7] Each student should examine each and ask themselves the question: "How much of each competency do I have?"

1. The ability to develop and be in touch with curiosities. Perhaps another way of describing this skill would be "the ability to engage in divergent thinking."

2. The ability to formulate questions, based on personal curiosities that are answerable through inquiry (in contrast to questions that are answerable by authority or faith).

3. The ability to perceive yourself objectively and accept feedback from others about personal performance nondefensively.

4. The ability to diagnose your own learning needs in light of models of competence required for performing life roles.

5. The ability to identify human, material, and experiential resources for accomplishing various kinds of learning objectives.

6. The ability to identify data required to answer various kinds of questions.

7. The ability to locate the most relevant and reliable sources of any required or acquired data.

8. The ability to select and use the most efficient means for collecting any required data from various sources.

9. The ability to organize, analyze, and evaluate the data so as to get valid answers to questions.

10. The ability to design a plan of strategies for making use of appropriate learning resources in answering questions or meeting learning needs.

11. The ability to carry out a learning plan systematically and sequentially. This skill is the beginning of the ability to engage in convergent thinking.

12. The ability to collect evidence of the accomplishment of learning objectives and have it validated through subsequent performance.

Schuttenberg and Tracy believe there are many different roles a facilitator should assume, including that of a leader, collaborator, or colleague, in promoting varying types of self-directed behavior.[14] In other words, a facilitator is not just a classroom teacher, but also can be a counselor, consultant, tutor, and resource locator.

There are at least nine learning variables that can be controlled by learners: [15,16]

- *Identification of learning needs* - Identifying the range of possible topics for a course or learning experience.

- *Learning goals* - Once needs have been identified, specific topics, purposes, and goals should be chosen by the learner and incorporated into a learning contract or plan. The facilitator and learner then can share in the refinement of this contract.

- *Expected outcomes* - The desired outcomes should be determined by the learner and related back to needs, topics, and purposes. The facilitator provides advice or offers concrete suggestions as needed.

- *Evaluation/validation methods* - Learners select the evaluation or validation methods and techniques that best suit their own learning styles or preferences. These can range from traditional tests to the use of experts who have been completely removed from the learning situation to serve as validators or evaluators.

- *Documentation methods* - Learners choose methods for documenting and demonstrating accomplishments to keep a record of learnings and to refer to after the learning experiences have ended.

- *Appropriate learning experiences* - Learners select learning experiences that suit their specific situations (mini-internship, reading or listening to audio tapes, etc.).

- *Variety of learning resources* - Provide various resources to suit personal needs and interests (e.g., textbook recommendations, a study guide, workbook of supplemental materials, suggested reading material, media materials, lists of resource specialists, and examples of student generated materials from previous courses).

- *Optimal learning environment* - Provide a mixture of instructor input, supplemental learning materials, discussion opportunities, evaluation options, and mechanisms for critical reflection.

- *Learning pace* - The self-directed learning process allows for much of the learning pace to be determined by the learner. Given the existence of organizational constraints like designated course time slots, learners must select a pace best suited to their individual needs and that fits the institutional constraints.

SDL in Engineering Curriculum
Nursing and medicine programs have been using SDL for decades. Other universities and colleges have incorporated SDL into their adult education programs. Those programs include

the Open University in England, St. Francis Zavier University in Antigonish, Nova Scotia, and Syracuse University's Adult Education Program. Regarding SDL in engineering courses, Litzinger et al. has conducted multiple studies.[17] The Self Directed Learning Readiness Scale (SDLRS) was administered to senior level engineering students. The relationship between SDLRS results and grade point averages was examined. Thirty-six and thirty-five senior engineering students took the SDLRS in 1999 and 2000, respectively. The students taking the SDLRS exam were Teaching Interns in the College of Engineering and therefore some of the best students based on course grades. The purpose of their study was to determine if there was any correlation between the students' SDLRS scores and grade point average. They found that there was no relationship between SDLRS and grade point average.

Additionally two problem based courses were developed in the Mechanical Engineering and Industrial and Manufacturing Engineering Departments to improve the students learning along with their readiness for SDL.[17] The two courses were *IME, Inc.,* which is a two semester undergraduate course where students design and produce new products in volume, and *Designing Product Families*, which is a graduate level course that involves traditional lectures, case studies, and learning activities. Students in both courses took the SDLRS before and after completing the course. The increase in SDLRS scores were statistically significant for both courses which meant that "the students' readiness for self-directed learning, as measured by the SDLRS, is being positively affected by the experience of engaging in self-directed learning within the two courses."

Litzinger et al. conducted another study on the readiness of engineering students for SDL.[18] In this study, students in a Mechanical Engineering capstone course took the SDLRS pre-course and post-course. The goal of the study was to determine if the capstone course affects the students' readiness for self directed learning. There were 47 students in the course, and 35 students completed the pre-course test and post-course test.

The post-test SDLRS scores showed that there was no statistical difference from the pre-test scores. The lack of statistically different pre-course and post-course scores revealed that the capstone course did not affect the students' readiness for self directed learning. However, the data did reveal some results. Some individual scores did show statistically significant differences between pre-course and post-course scores. Some individual scores increased, while other decreased. The decrease in post-course scores was further examined. It was determined that a mentor working with one of the capstone groups had too high of expectations from his/her group, and the high level of expectation by the mentor appeared to have a negative affect on the students in his/her group. On the other hand, a group where the students were required to learn more material on their own exhibited a significant increase in post-course SDLRS scores.

Conclusions
Self directed learning (SDL) has been used for many decades and has been shown to foster higher learning in students. SDL requires that the student assume ownership of their own learning and not to expect the teacher to hand them the answers. The literature has shown that courses can be developed to improve the students' readiness for SDL, but the courses, projects, and mentors must be chosen wisely. This teaching methodology can be used in engineering education to improve students understanding and to give them the tools to be life long learners.

References

1. Felder, R., and R. Brent (2005). Understanding Student Differences, *Journal of Engineering Education*, 94 (1), 57-72
2. Felder, R., and J. Spurlin, (2005). Applications Reliability and Validity of the Index of Learning Styles, Vol. 21, No 1, pp. 103-112, *International Journal of Engineering Education*, Great Britain
3. Kolb, D. A. (1984). *Experimental Learning Experience as a source of Learning and Development*, Prentice Hall- Englewood Cliffs, NJ.
4. Rudner, L. (1999) The Scholastic Achievement and Demographic Characteristics of Home School Students in 1998, http://www.hslda.org/docs/study/rudner1999/ Rudner0.asp.
5. Ray, B., (1997). Home Education Across the United States, National Home Education Research Institute (NHERI), http://www.hslda.org/docs/ . Salem, OR.
6. Cross, K. P. (1981). *Adults as Learners*. Jossey-Bass Inc., Publishers, San Francisco, CA.
7. Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers.* Associated Press, New York, NY.
8. Piskurich, G.M. (1993). Self-Directed Learning: A practical Guide to Design, Development, and Implementation. Jossey-Bass Inc., Publishers, San Francisco, CA.
9. Gibbons, M. (1974). *Walkabout, Searching for the Right Passage from Childhood and School*. http://www.selfdirectedlearning.com/walkabout.html
10. Confessore, G.J. and S.J. Confessore. (1992). *Guideposts to Self-Directed Learning: Expert Commentary on Essential Concepts*. Organization Design and Development, Inc., King of Prussia, PA.
11. Durr, R. (1995). Integration of self-directed learning into the learning process at Motorola. In H.B. Long and Associates, *New Dimensions in Self-Directed Learning*. Public Manager Center, University of Oklahoma, Norman, OK
12. Hiemstra, R. (1997). Self-Directed Learning: Present and Future. Conference paper at the First World Conference of Self-Directed Learning. September 14-17, Montreal CA. http://home.twcny.rr.com/hiemstra/montrsdl.html
13. Montessori, M. (1912). *Montessori Method*, Fredrick A. Stokes Company, NY, NY.
14. Schuttenberg, E. M., and S.J. Tracy (1987). The role of the adult educator in fostering self-directed learning. *Lifelong Learning: An Omnibus of Practice and Research, 10*(5), 4-6, 9.
15. Cooper, S. S. (1980). *Self-directed learning in nursing*. Nursing Resources, Wakefield, Massachusetts.
16. Hiemstra, R. (1988). Self-directed learning: Individualizing instruction. In H. B. Long and Associates, *Self-directed learning: Application & Theory* (pp. 99-124). Athens, Georgia: University of Georgia, Adult Education Department.
17. Litzinger, T, Wise, J, Lee, S, Simpson, T, and Joshi, S. "Assessing Readiness for Lifelong Learning", Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition.
18. Litzinger, T, Lee, S, and Wise, J. "Engineering Students' Readiness for Self-Directed Learning", Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition

Biographies

Findlay G. Edwards, Ph.D., P.E. is an associate professor of environmental engineering at the University of Arkansas in the Civil Engineering Department. 479-575-4456, edwards@uark.edu

Tommy C. Daniel is a professor of waste management-water quality at the University of Arkansas in the Crop, Soil, and Environmental Sciences Department, 479-575-5720, tdaniel@comp.uark.edu

W. Micah Hale, Ph.D., P.E. is an assistant professor of civil engineering at the University of Arkansas in the Civil Engineering Department. 479-575-6348, micah@uark.edu,

Adrian T. Hanson, Ph.D., P.E. is an associate professor of environmental engineering at New Mexico State University in the Civil Engineering Department. 505-646-3032, athanson@nmsu.edu

EE Richardson, Ph.D., P.E. is a consulting engineer at AegeanC Consulting and a lecturer in the Engineering Technology Department at New Mexico State University, 505-373-0870, ege@AegeanC.com