Advanced Student-Centric Learning Practices in Applied Engineering Programs

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Abstract
Student-Centric Learning (SCL) has been recognized as an effective methodology to engage and motivate students for some time now. Research conducted by National Training Laboratory and other leading universities have identified several benefits of SCL including deeper learning, motivation, teamwork, etc. With the advent of high-speed internet technology, availability of large data bases brimming with information and the rapid growth of online course offerings, SCL has been taken to another new higher level, thus empowering students like never before.

Different types of SCL techniques have been successfully implemented in MS Sustainability Management, MS Engineering Management and MS Environmental Engineering programs. Graduate level applied engineering programs are offered through onsite live classes and online classes. The specific SCL techniques used include:

- Knowledge-centric SCL promoting development of critical thinking by applying learned outcomes to real world problem-solving
- Learner-centric SCL promoting students to be more creative and use of prior knowledge
- Assessment-centric SCL promoting opportunities for feedback and improvement
- Community-centric SCL promoting interactions among the learners for sustained learning

This paper presents specific examples of the advanced SCL techniques/exercises used in different online or onsite courses, along with associated assessments. Charts with students’ feedback on the SCL practices will also be presented. Students’ feedback on their learning experiences through SCL has been positive. The paper will also discuss the future of SCL, the opportunities it provides for student empowerment and the rapid change from passive to active learning with technology as a key enabler.

Introduction
The National Research Council (NRC) in its 2012 report to congress identifies the need to instill twenty first century knowledge and skills - problem solving, critical thinking and communication - in order to navigate the rapidly changing world, and these skills should promote “deeper learning” [1]. Deeper learning helps the students to better master the subject matter by going beyond the routine learning and thus helps them to develop knowledge and skills to solve problems in today’s workplace. Students who are armed with these tools would have a competitive edge.

Student-Centric Learning (SCL) practices are tools that promote students’ deeper learning, empowering and engaging students (cf. T4SCL Report by European Student’s Union and Educational International, 2010 [12]). Universities have a unique responsibility to teach twenty first century skills which are immediately applicable in work places. Bloomberg [13] in her many publications and research has written and trained faculty for ‘Learner-centered teaching’, resulting
in SCL. Two key traits of SCL - empowerment and engagement - put the learning and teaching of these skills on center stage.

Technology with its vast advancement and capabilities (e.g. Internet, hi-tech learning tools), has become a key enabler in today’s teaching and learning environment. Technology has helped both the students and the instructors. Learning environment has gone from a class of tens of students to hundreds in ‘onsite live’ classes while the online learning environment with Massive Open Online Courses (MOOCs) are registering tens of thousands of students. An online class, in addition to posing many challenges to instructors and the students, by design provides a SCL environment.

SCL learning and teaching practices have been implemented at graduate level programs in the Applied Engineering department. This paper will discuss several of the practices used in three programs (MS Sustainability Management, MS Engineering Environment and MS Engineering Management). Student feedback from several courses will also be presented and discussed. These SCL techniques were practiced both in the onsite (live) classes as well as online classes. This paper will also discuss some of the faculty questions being raised regarding SCL and on the future impacts of technology.

**Student Centric Learning Practices Background**

Literature survey credits the concept of SCL to Hayward and the writings of Dewey (1956), and more recognition for this methodology came during the 80’s and 90’s [2]. Early discussions were focused on the shifting of power from the teacher to the student: empowering the students, expand and encourage interaction among students and changing the major information flow away from one-to-many (old traditional instruction). In another well-known research by Craik and Lockhart, it was proven that learning and retention are related to the depth of mental processing [3]. The practices and techniques of SCL engage students in a very active manner where continuous mental processing is required, thus leading to higher retention of the subject matter.

The Council on Science and Technology at Princeton University has identified several methods of Student-Centered Teaching methods [4] (also referred to as Student Centric Instruction, SCI). These methods range from small group discussions to case studies to computer simulations and games (or *gamification: process of learning through games; referring to the design/creation, play and demonstrating a game in support of course learning outcomes*). The objective of each of these practices or techniques is to get the student to engage, to participate making the learning ‘active’ and not ‘passive’ (referring to the traditional lecture with practically no interaction with the instructor or among the students). In other descriptions, it is also stated that when SCL is properly implemented, it can lead to increased motivation to learn, greater retention of knowledge, deeper understanding, and more positive attitudes towards the subject being taught [5].
One of the key reports released by National Research Council recommended that learning environments can be organized into different categories or focus areas, namely, knowledge-centered, learner-centered, assessment-centered, and community-centered [6]. Knowledge-centered learning mainly refers to students ability to transfer their learning to critical thinking and problem-solving skills; learner-centric approach refers to the ideas and information the students bring on their own from their prior learning or other experiences; assessment learning approach gives the students quick feedback on how the students meet the course learning outcomes, and to help improve (or turn around); community-learning refers to the opportunities that help promote interactions among the students and thus learn from each other. This also gives each student opportunity to become a teacher under this category, fostering communication and teamwork.

The different SCL practices implemented and discussed in the paper can be identified with one of the above four categories. The type of environment and exercises provided in different classes were to help students to fully participate and be engaged - in other words, for students to be engaged in active mental processing. Table 1 refers to some of the key differences between Instructor-centric (passive learning) and student-centric (active learning). It is clear from the active learning process or SCL, there is a high degree of mental processing involved – both individually and through interactions.

<table>
<thead>
<tr>
<th>Passive Learning Process</th>
<th>Active Learning Process (Student-Centric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus is on Instructor</td>
<td>Focus is both students and Instructor. High interaction between students and the instructor</td>
</tr>
<tr>
<td>Students Work Alone</td>
<td>Students work in teams or alone depending on the purpose of the activity</td>
</tr>
<tr>
<td>Instructor answers students’ questions, if any</td>
<td>Students actively participate in class discussions and instructor facilitates; instructor initiates a class dialogue with an opened ended topic or a question</td>
</tr>
<tr>
<td>Instructor chooses topics</td>
<td>Students choose or initiate topics for discussion</td>
</tr>
</tbody>
</table>

Table 1 – Summary of Differences between Passive and Active Learning Processes (SCL)

Another widely referenced popular learning pyramid published by the National Training Laboratories, assigns various average learning retention rate for the different types of learning methods or practices – see Figure 2 [7]. It is clear from the different methods, retention rates are much higher with active learning using SCL type practices.
SCL in Technical Education

Literature is full of research for SCL practices implemented for teaching subjects – from languages to science to engineering (or technical) education. At our university, SCL practices have been introduced in two departments – Computer Science and Applied Engineering. This paper will cover the details of advanced SCL practices in the Applied Engineering department in the following graduate programs – MS Engineering Management (Online and Onsite), MS Sustainability Management (Online and Onsite) and MS Environmental Engineering (Onsite).

Although each of the above programs addresses different majors, the SCL techniques or practices were similar and to some extent tailored to the courses in each program. The general theme being: facilitate high levels of student engagement and assess them on their engagement (feedback).

Since technical education deals with more ‘quantifiable’ subject matter, SCL practices fits really well for engineering courses.

Implementation of Advanced Practices of SCL

The different SCL practices implemented will be framed within the four categories or areas as noted earlier. Specific practices implemented for each category will be discussed. It is to be noted that the implementation of these practices are limited to the three specific programs in our school and are still in their initial stages at the graduate level – not implemented in all courses. Different SCL activities will be discussed first followed by students’ feedback.

Knowledge-Centric SCL

The main learning base here is to focus on developing critical thinking and data synthesis. Two practices have been implemented for this SCL – ‘News of the Day’ and ‘Debates’.
For ‘News of the Day’ - onsite students in the different courses participate in this activity. The objective is to identify a recent development in the news media or an event that occurred within the last 30-45 days, from any relevant and reputed magazine or newspaper or journal. The news item or event should be directly related to and meets one or more course objectives, and an URL link is available. Each student will post the URL link in to the course home-page (Wibliography) and talk to the topic for 5 minutes followed by a brief Q&A session. The activity has a certain grade allocation associated with it for class participation. Each student will identify the source and event (or news), location, how it is tied to the current course and its importance. The student will also discuss quantification as applicable to the subject matter being taught. Students are also expected to interpret the news or event as they see it and give their opinion (positive or negative). As noted, this is an exercise in critical thinking and data synthesis (students can discuss other related events). The instructor publishes a schedule for all students. The News of the Day discussion is at the beginning of each class (two or three students present in each class). This approach engages the students from the beginning of the class to be active, attentive and engage.

As an example – in the Engineering Management Concepts course, the students will look for a management related news or event and present it. They could be on human resources management, engineering management or engineering ethics, etc. The student opens the URL for the class and starts the discussion. In the Sustainability courses, students will bring news items (or events) directly relating to the sustainability – energy, water, environment, policy, equity or economics. In the Globalization class, with so much going on the world today students bring latest topics on global events (as it impacts economy, culture, trade, environment, etc.). This SCL practice gets away from the expectation that the instructor comes in and start a lecture and all students have to do is be passive and listen. In the News of the Day SCL activity, students get engaged and active right from the beginning of the class.

For ‘Debate’ SCL activity - this is implemented in the Globalization class where teams (or individuals) take a position whether globalization is ‘good’ or ‘bad’ (this is a huge topic in today’s world), and present their case with a current example and quantification to the class followed by a brief Q&A session. Again, students engage quickly and add to the discussions and refer to events from their own companies.

Although text books these days come up with new editions more often than before, this SCL activity keeps the students informed about the latest happenings in the subject they are learning. Students’ feedback comments reflect that they are anxious to hear about the latest developments as they come to each class – they have a different expectation at the beginning of each class.

Learner-Centric SCL
The main learning base here is focused on learners becoming ‘creators’ with their own ideas which advances creativity/innovation and uses any and all prior knowledge the learners might bring to the table. This is a team activity and involves the student-teams designing, creating,
playing and demonstrating a game that is relevant to the subject matter and supports course learning outcomes. In this SCL practice the course team project will be quantified and demonstrated through a game that the team will design, create, play and demonstrate. Teams are given full freedom (empowered) to create/innovate and even to adopt any existing game to suit the project under study. This SCL has been successfully implemented in more than one course in the MS Sustainability Management program. This particular SCL is perhaps one of the most advanced SCL used in the graduate classes since real world problems need to be well understood to be able to bring the concepts down to game objective(s), rules and winning strategy (games have been used in school education and is well documented). Sustainability topics are somewhat new in higher education and the concepts (such as Equity) are difficult concepts for students to understand. But making this practical with gamification brings home the concepts when they are quantified. Deep learning happens. Many students bring their prior gaming experiences to bear for the gamification process, and help others who may not have that experience by teaching them.

In a gamification approach, student engagement, teamwork, innovation and competitiveness come in to play. With a game, subject matter is no more a theory, but practical and aids in students’ understanding. Students have to do significant research to come up with game rules and to quantify the subject matter. Everyone is actively involved or engaged in one or more aspects of a game resulting in high mental processing and thus leading to higher subject matter retention. This is also an opportunity to demonstrate leadership and teamwork skills. This approach has been implemented in both onsite and online courses. In addition, this SCL also makes learning fun and provides opportunities for students to learn additional tools (e.g. Game board design).

**Assessment-Centric SCL**

In addition to the standard assessment tools (e.g. quizzes and exams), this particular SCL approach centers around one or more course homework leading to a specific deliverable from the real world implementation of an advanced topic like ISO14001 Environmental Management System or Renewable Energy Alternatives. Students present both the theory and implementation.

This is a team oriented SCL in line with course learning outcomes. In fact, the students have to come to speed on many of the ISO 14001 standard details on their own (from a secondary textbook for the course), research to find an industry implementation that meets the standards, and present it to the whole class. The students are empowered to critique the implementation and recommend changes or improvements to the current implementation. This again is an advanced SCL at the graduate level helping further development of critical thinking skills and students are motivated since it is assessment-centric. This SCL activity broadens their own career due to the nature of work involved and learning. As most students would agree that just reading a standards textbook could become boring – but tied to real world implementation brings the theory live to present and discuss with their cohorts.
Community-Centric SCL
The focus here is on learners themselves becoming teachers to some extent, and thus it raises the level of mental processing (or learning) and increase interaction among learners. This can be an individual or team SCL activity. As noted earlier, in the learning pyramid, it was recognized that the highest retention (90%) occurs when teaching others is involved. This approach puts the students in a different mind-set – to explain, to answer questions, etc. A teaching SCL activity helps graduate students not only to improve their preparation & presentation skills but also concept-articulation skills. This is very important for a leadership position or even for presenting to a company C-level management. When student team prepares a presentation with the idea of teaching the same to their classmates, the approach is thorough with strong team interactions. Idea exchanges and teaching happens. All these inherently increase learning and retention.

Three SCL activities that are practiced in this category are: teaching sustainability principles with an example, ice-breaker discussion activity and student selecting text book chapters to present/teach.

In the first SCL activity, student teams (or individuals) present the theoretical concepts of a sustainability principle (from a secondary course text book): its official name, definition, origin, its specific principles and an application or implementation that demonstrates the principle. Students need to really think deeply about the sustainability concept and be able to explain as if they are teachers. This content is included in their exams.

In second SCL activity, called icebreaker discussions, is implemented primarily in MS Engineering Management course where issues of management and customers relationships are discussed at length and its importance. From a process perspective - the class is divided in two sections, one section is the management and the other is the customer (role playing). A real-life issue is presented by the instructor and students discuss the issue from their role’s point of view. Each section presents a potential solution to the other and negotiates. The roles are switched for another real-life issue so the students get to think beyond theory and to put forward practical solutions. This real live simulation, facilitated by the instructor, promotes management and negotiating skills at the graduate level.

In the third SCL activity in this category, student teams get to pick a chapter of their choice in the primary text book and present it to the class (like teaching, of course) along with an real world example highlighting the theme or core concept of the chapter (e.g. Engineering Ethics). The students also get to vote picking a sub-set of these chapters that will be included in the exam – a true democratic process of student empowerment - decide on what they are most interested in to learn and to be assessed on.
Student Feedback on SCL Activities
As a part of the initial implementation, it was very important to get students’ feedback on these graduate level advanced SCL practices. Surveys were taken at the end of the courses where one or more of these SCL practices were implemented. Students were informed about these activities right in the beginning as parts of course outline along with assessment points allocations for specific SCL practices (e.g. News of the Day). In these graduate level courses most of the students are working adults and so their feedback is very significant and unique. The following charts indicate the feedback from different courses – responses to specific questions asked in each of the courses as it related to SCL practices.

The Charts in Figures 3 – 6 represent the student feedback on the various categories of SCL practices shown with 1 standard deviation error bars, and sample sizes in each case (5 being the most favorable/highest rating). It also should be noted that statistical ‘mode’ for all these feedback was a 5.

**Figure 3 Knowledge-Centric:** Student Feedback on ‘News of the Day’ and ‘Debates’
Figure 4 Learner-Centric: Student feedback on an array of questions for gamification — Learning through Games; Game Design Methodology (GDM) is the gamification process.

Figure 5 – Assessment-Centric: Student Feedback on ‘ISO 14001 Presentations’
Specific questions about the various traits of SCL (e.g. motivation, innovation, etc.) were asked in the *gamification* example (Figure 4) – student feedback is overwhelmingly positive for these traits (all above 4 rating).

It is clear from the above charts, that overall the SCL practices were very well received by the students. They see the value in the practices through not only very good ratings on the surveys, but also in their comments. As noted earlier, these practices are not widely implemented yet and these are the results from our initial implementations. These results cannot be generalized for all programs since there are other factors that could have an impact. The other variables are instructors, their style, facilitating and mediation skills on how these practices themselves are presented for a given course – each Faculty is different and may differ by courses as well. More research and data collection would be required which would include these factors. Another key item to be researched to check if the students overall do get better grades when these practices are implemented.

**Online Education - A Catalyst for SCL Practices**

The advent of online education in higher learning and its rapid growth in the last 10 years is primarily based on the premise that students want to learn on their time (asynchronous), thus demonstrating their empowerment. Online learning by design puts more responsibilities on students shoulds for self-learning since there is no face-to-face lecture or class time per say (except for some synchronous chat sessions depending on the course and the university). Some
blended (or hybrid) classes may have some face-to-face lecture times. Nevertheless, online class-
learning by default is a catalyst of self-learning.

According to Palloff & Pratt \[8\] the following are specific online educational attributes and online
student responsibilities:

- Online learning is learner-centered and learner focused
- Learner focused online teaching needs a community amongst the learners
- Collaboration among the learners
- Instructors empower learners to take charge

The practices and techniques of SCL meet all the above online educational attributes and have the
potential to go beyond with *technology* as the enabler.

With the help of Internet technology, a huge step forward for online learning is the development
and deployment of Massive Open Online Courses (MOOCs). MOOC has been at the forefront of
leading US universities (e.g. MIT, Stanford, Harvard, UC Berkeley) with the goal of expanding
online education for *free* from the best universities and professors \[9, 10\]. Registrations for MOOC
classes run in to tens of thousands of students from around the world. This mode of education is
another stage or platform for SCL practices to develop worldwide with self-motivation and student
empowerment being the key attributes. Although MOOCs initially started only for engineering or
technical classes, they are moving towards offering humanities related subjects, such as Sociology
and Anthropology.

**More thoughts on Impact of Technology on SCL**

It is no secret that the advancement of technology has had a huge impact in higher learning both in
the US and around the world. The impact of Internet technology was discussed earlier. It is not
uncommon to hear about social media’s potential that one day it might become the media of
instruction, not to mention the arrival of ebooks and its impact on the traditional text books and its
associated industry – a disruptive technology indeed. It can be argued that technology will make
education more open, mobile, social and analytical.
There is more than that meets the eye – the overwhelming development of wireless network seamlessly integrated with wired technology (e.g. cable modem, routers,) and the adoption of wireless devices (e.g. cell phones, tablets, home Wi-Fi, hot spots) is further changing teaching and learning logistics. IT departments in higher education are at crossroads deciding on the best approaches that can support Faculty and students with high availability and security for a multiplicity of devices. This adoption further reinforces and empowers students with the ubiquitous access to information (see Figure 7). In the recent past the advancement of cloud computing technology has taken access and sharing of information to another level furthering the ubiquity around the world. The X and the millennial (or Y) generations will form the bulk of adult higher education in the near future, have uniquely settled on these wireless technologies (and social media) and are very comfortable with it. They are also looking for quick/immediate and timely feedback on their class performance, and SCL practices can help to provide for this quick feedback. This needs further changes in how Faculty can work under these new norms which will be new a lot of the current faculty. They need to prepared and trained – university IT departments and Learning Management Systems (LMS) will play a huge part in this transition.

Although MOOCs are in their early adoption stage, one can predict that it will lead the way for higher education’s impact being more open, mobile, social and analytical further pushing the student-empowerment-envelope with SCL practices.

**Addressing Questions on SCL**

As was discussed earlier, although student feedback on SCL practices has been positive, this needs more research and data collection & analysis (larger sample sizes) done before generalizing them for their effectiveness and large scale adoption in engineering education. Concerns and questions will be from the Faculty themselves before they would implement the practices.

Texas A&M University Professors[^11] addressed various Faculty questions as it relates to SCL and have documented several examples and practices that help the Faculty. They addressed faculty questions like, ‘Can the content in the syllabus be covered using SCL learning approaches? Can this approach be used for small and large classes?’ Their research also suggested solutions and resources to address them: ‘how to respond to those students who might resist this approach and how to help better team work’, etc. Again, implementing many of these for both online and onsite classes would need to be tailored for each type of course offering.

It was observed during this initial implementation that generally students expect to be passive when they come to an onsite class. It is a challenge to draw the online students in to highly interactive discussions mainly due to time limitations for synchronous activities (online classes are by default asynchronous). The online Discussion Board activity (an assessment vehicle) provides one method to draw the online students to actively participate with open ended questions and

[^11]: [Texas A&M University](https://www.tamu.edu)
empowering them to initiate new topics for discussion. Other team SCL practices as discussed above can also be implemented for online classes.

Instructor’s skill to articulate and mediate the specific SCL practices also plays a big role in students buying-in and practicing SCL. Further, *one size fits all* approach may not work in certain programs and the SCL practices may need to be tailored at the Instructor’s initiative and innovation.

**Conclusion**

Universities can do more to instill deep learning among their students in order to prepare them for the twenty first century jobs. This is even more important for engineering education. Practicing active learning through different SCL activities is a very practical way to instill critical thinking, innovation, participation, collaboration or teamwork. Several advanced SCL practices implemented in three Master’s level engineering program courses were presented and discussed in this paper. It is clear from students’ feedback that the SCL practices were well received and the students felt that they were empowered and it helped with better understanding of the course concepts.

The practices discussed here were the initial implementation and the feedback are from limited courses in three programs and as such the results cannot yet be generalized with a formal template for future for all engineering programs. More research needs to be done with other factors such the direct impact of the instructor and the mediation involved. Another area that needs further research (for tools and techniques) is the ability to measure if the overall student performance (e.g. individual and class average course grades) improves with consistent SCL practices and if they are higher than those courses where SCL is not practiced.

Higher education will continue to experience big changes due to fast changing technology and its influence will further result in empowering students with ubiquitous data becoming available through Internet and other high-tech media.
References

2. Geraldine O’Neill and Tim McMahon; Student-Centred Learning: What does it mean for students and Lecturers?; 2005

Acknowledgement
The author wishes to express his sincere thanks and appreciation to all his students who were important part in these SCL activities and its implementations in the various courses.