An Effective Systematic Approach to Migrate a Bachelor of Science in Computer Engineering Degree Program to Online Modality

Yanzhen Qu
Colorado Technical University
Colorado Springs, USA
yqu@coloradotetech.edu

Richard Cai
Colorado Technical University
Colorado Springs, USA
rcai@coloradotech.edu

Ricardo Unglaub
Colorado Technical University
Colorado Springs, USA
runglaub@coloradotech.edu

***Abstract*- During the last two and half years, the Covid-19 Pandemic has made online learning environment (OLE) a necessary modality for all educational degree programs globally. However, migrating a conventional ground campus only Bachelor of Science in Computer Engineering (BSCE) degree program into an online modality is a project more complicated than simply replicating what is common in an on-ground classroom into a virtual classroom. The major challenges include how to maintain instructional effectiveness in an online modality, how to enable students accessing lab equipment to conduct hands-on experiments in an OLE, how to support students expeditiously when they encounter difficulties in an asynchronous communication based OLE, and how to assess students work produced in an OLE, etc. In this paper, we share our experience on how we applied a systematic approach, guided by various learning pedagogies, migrating a ground campus only ABET accredited BSCE degree program into the online modality successfully. Our practice has demonstrated that this approach can assist us to quickly identify solutions, quite often unique to the OLE, based on the specific characteristics of online modality to effectively address various typical challenges encountered during the process of migration.**

Keywords—Online Learning Environment, System Engineering Management, Experiential Learning, Competency-based Learning, Adaptive Learning, BSCE

I. INTRODUCTION

Since early 21st century in the USA, the Online Learning Environment (OLE), along with the fast development of computer networks, has become an optional academic modality for higher education. However, during the last two years, the Covid-19 Pandemic has made OLE a necessary modality for almost all educational degree programs at every subject and every degree level globally [1,2,3].

As anyone in the educational industry can imagine, moving the classroom of any educational institution from the traditional ground campus to the virtual classroom based on an OLE is a task much more complicated than simply provide students a user name and password for accessing a website that hosts the virtual classrooms on an OLE. This is because a campus of any educational institution is a system consisting of many functional departments that support the various needs of students, faculty, and administrative staffs. There are many dependencies and interactions among these functional departments. To enable a degree program to effectively run on an OLE, most of these functional departments must also be web-capable and integrated with an OLE so that students, faculty, and administrative staff can all easily access them via the OLE at the times when they need to access these functionalities.

In higher education institutions, among all the degree programs, the engineering degree program is the hardest one to convert to online modality mainly because most of engineering degree programs, based on the experiential learning pedagogy, have quite many courses having assignments that require hands-on labs support, which is much harder to deliver on an OLE.

One of features of an OLE, which is different from the traditional ground campus, is that most of the time, an OLE runs under the asynchronous communication mode such that the two parties in the communication are not present simultaneously to sustain a conversation. This has posed another challenge, which has direct impact on the students' learning effectiveness when learning via an OLE: how to enable the effective engagement between either student-faculty or student-student in an OLE.

Other challenges include how to maintain instructional effectiveness in an online modality, and how to assess students' works, and how to review the program's outcomes. All these challenges have further indicated that migrating a degree program to the online modality is indeed a complicated system engineering management project, which require special attention and effort with a comprehensive planning with a focused execution.

In this paper, we share our experiences on how we have applied a systematic approach, guided by various learning pedagogies, that make the process of migrating a ground campus only ABET credited BSCE degree program into the online modality successful. Our practice has demonstrated that this approach enables us quickly identify solutions, which quite often unique to the online learning environment, based on the specific characteristics of the online modality to effective

address various challenges encountered during the migration process.

II. Related Works

This section presents some of the research works that are related to the particular research subjects of this paper.

A. Online Learning Environment

The Online Learning Environment (OLE) is a web application used to deliver course via student learning objectives. The backend of the OLE is a Learning Management Systems (LMS), while the frontend of the OLEs is the Virtual Campus (VC) which has provided an interface and interactive learning tools to students and faculty to conduct classes online. According to [4], cognitive, social, and teaching presence were significant factors in learners obtaining high-level outcomes using OLEs. Additional studies further noted that the importance of online learners being just as valued as face-to-face learners from a communications frequency perspective. Instructor responsiveness is also a key factor in success [5]. Learner content interaction and Learner instructor interaction were also identified as primary factors in [6]. In recent years, OLEs have also shown to be effective in teaching students programming. Roshni & Choon [7] observed that interaction through peer reviews in an online programming environment is beneficial to student learning. The perceived value of online learning has increased as the education system faced constraints due to the pandemic caused by COVID-19. These challenges included social, emotional, and cognitive obstacles where the instructor was required to play a key role in facilitating student and leaning system interaction. Effective and frequent communication through tools such as Zoom helped to motivate students and achieve the required learning outcomes [8]. According to [9], written feedback provided in a suggestive manner also proved effective in an OLE.

B. Experiential Learning

After several decades' of development, the experiential learning, represented by Kolb's model [10], which abstracts the learning as a "life cycle of four phases: concrete experience, reflective observation, abstract conceptualization, and active experimentation", has become the most influential model for teaching and learning [11, 12]. "Experiential Learning focuses on doing an activity and then processing that activity from both a content and personal perspective. It intentionally has a place for open questioning that takes learners through a reflective process, allowing them to make personal and global connections to the learning. It provides a structured pause, called "generalization," where new or missing information can be introduced or added. It stretches learners to look at new ways to apply life skills and knowledge" [13]. With proper design and planning, the experiential learning can be effectively applied in both on ground and on-line modality and any subjects relevant to STEM [14]. Needless to say that for BSCE students, it is very important that they can gain hands-on skills commonly required by professional jobs that are related to computer engineering such as software programming, trouble-shooting, system testing, etc., even in an OLE.

C. Competency-based Learning

"Competency" is defined as the integrated application of knowledge, skills, values, experience, contacts, external knowledge resources and tools to solve a problem, to perform an activity, or to handle a situation [15]. For the degree programs targeted to the working adults, competence-based learning is not only a welcomed concept, but also the best practice. Because one of the key elements of the competence-based learning is that the learning content is customized, based on each student's current competency level. Before introducing the new course materials of each learning subject, the student is required to take a preliminary test to assess his/her knowledge on the subject. Based on the result of such an assessment, the learning materials are tailored to the student's knowledge. This approach of learning has become the most important pedagogical guidance for any adaptive learning educational paradigm [16, 17].

D. Adaptive Learning

During the last decade, adaptive learning advocates have promoted its potential for transforming higher education. "Over 30 software vendors have entered the adapted learning field. Some of the older and larger vendors include McGraw Hill Education, Knewton, D2L, and Realizeit. Colleges and universities are at the beginning stages of implementing adapted learning [18]". In fall of 2015, bolstered by a $4.6 million-dollar grant from the Bill and Melinda Gates Foundation, a competitive grant opportunity was offered by the Association of Public and Land-grant Universities (APLU) for its 237 member colleges and universities that want to enhance personalized learning, utilize technology for proactive advising, and accelerate degree completion rates [19]. Dziuban et al. discussed the history of adaptive learning research and various adaptive learning tools and systems [20].

Realizeit [21] is an adaptive learning platform capable of incorporating multiple learning resources such as video, audio, testing, objective test questions, exercises and case studies into the curriculum. It incorporates probabilistic reasoning using Bayesian estimation procedures within an instructor-created learning network [22]. Cerego is another adaptive learning platform based on principles of neuroscience and cognitive science [23]. It has instructional design support with Open Educational Resources (OER), real-time media, standards-aligned content, lesson plans, and learner-generated materials. Preliminary results from a study conducted at Excelsior College in 2014 indicated that using Cerego can help students increase grades when studying math and biology online [23]. LearnSmart is an adaptive learning tool offered by McGraw Hill. Qin Sun, et al. who examined its impact on student learning effectiveness and their regression analysis results showed that the use of LearnSmart improved students' perceived competency, thus increasing their perceived value of using LearnSmart, as well as their satisfaction with LearnSmart [24].

E. Continous Assessment

Continuous assessment is another popular practice closely associated with adaptive learning software tools. It refers to the two abilities of the adaptive learning software tools: the ability to provide an immediate grading to any assignment that students just completed; and the ability to allow students to rework any assignment at any pre-defined frequency to improve the learning outcome for any course context [25]. These capabilities are very suited for OLE especially when combined with the practice of the competency-based learning and adaptive learning as described in the previous paragraph. This practice somewhat compensates for the difficulty caused by the typical asynchronous communication of OLE, and "as frequent assessment provides a feedback mechanism ensuring students are properly aligned with a scaffolder learning process [26] [27]."

III. Problem, Hypothesis & Research Questions

A. Problem Statement

Migrating a ground campus based BSCE degree program to online modality is a complicated system-engineering project. It presents several challenges including how on an OLE to provide students cost-effective hands-on labs; maintain timely high-quality engagement between either students and faculty or students and students, enable easy access to various academic services wherever and whenever needed, conduct fair and meaningful assessments to students' learning, etc.

B. Hypothesis Statement

By applying the principles of system engineering management and various learning pedagogies, we can develop practical strategies to ensure students in an OLE to study as effectively, so that they can gain the required knowledge and skills to meet the rigorous standards of engineering courses, and the program outcomes of the BSCE degree program.

C. Research Questions

Based on the problem statement and the hypothesis statement, we can derive the following research questions:

How can we apply the principles of system engineering management and various suitable learning pedagogies as the guidance to develop a set of practical strategies effectively addressing the challenges occurred in the process of migrating a BSCE degree program to online modality?

IV. Research Design

In this section, we will present our research framework that illustrates the principles that we used to guide us to resolve a set of challenges that migrating a ground campus only BSCE degree program to the online modality. The Research Framework consists of two portions: (a) Application of System Engineering Management Principles, (b) Use Cases of how we have applied various learning pedagogies to address typical challenges occurred in the process of migrating the BSCE degree program to the online modality.

A. Apply Systems Engineering Management Principles

In contrast to the intuition of most people that migrating a BSCE degree program originally designed for a ground campus modality mainly just need an online platform where both faculty and students can login and have a dialog, so that the main change is just moving the classroom from a ground campus to an online virtual classroom. If we think about a school as a system, and from the system architecture's point view, the traditional ground campus and the online virtual campus have two very different system architectures.

The ground campus based learning environment is a "centralized system" in which the campus is a place where either an individual student or a group of students can easily access any services needed, including classrooms, instructors' offices, labs, libraries, bookstore, finance department, admission office, registrar office, Veteran Affairs office, sport fields, swimming pool, and even dining hall or cafeterias. The basic communication mechanism used by students and service providers are mostly via in person synchronous communication mechanism.

The virtual campus based OLE can be categorized as "a distributed system" in which many services are not available from the same platform, or not directly accessible from the main platform by either an individual student or a group of students. The basic communication mechanism used by students and service providers consists of online asynchronous communication mechanism.

Caused by the fast spread of the COVID-19 pandemic, almost all schools were forced to quickly setup an OLE that can at least support some of the basic learning management functionalities via the virtual classrooms, so that students and faculty could at least continue their classes in the virtual classrooms.

However, for students in the BSCE degree program, just having online lectures is not sufficient. The first challenge is how to perform their lab projects at the time when the labs at the ground campuses were closed. Also, library is another critical service to our students. Even many books now have digital format, without an integrated interface between the online learning platform and the school's library system, students will be slow down significantly when they need to access the library services. Additionally, because the system architectures' difference between traditional ground campus and online virtual campus, the things like class schedule, assignment due dates, the workload of the weekly assignments, as well as test/assessment frequency and format, might all need some updates in order to provide students a meaningful and manageable learning experience.

Migrating an originally ground campus based BSCE degree program is a complicated project because many services required by students, faculty and administrative staffs cannot be integrated into the virtual OLE in a short period. Therefore, we have applied the principles of systems engineering management to define a three-year plan to migrate our BSCE degree program from the on-ground modality into a combination of both on-ground and online modalities. The five principles are: (a)

principles govern process, (b) seek alternative systems perspectives, (c) understand the enterprise context, (d) integrate systems engineering and project management, and invest in the early stages of projects. "A common thread behind the principles is a desire to foster the ability to anticipate and respond to a changing environment with a constant focus on achieving long-term value for the enterprise."[28, 29]

Based on these principles, we produced a list of tasks that the project of migrating of the BSCE degree program to online modality shall contain. We then associated these tasks with the corresponding principles so that we can clearly know each task's context and priority, as shown in TABLE 1.

TABLE 1. Migration Tasks and Their Associated Principles

Principles	Tasks
principles govern process	• Establish project plan • Review plan • Approve plan
seek alternative systems perspectives'	• Identify EE Kit for students used at home to do EE labs projects • Identify supplier and logistic vender • Identify Tech Support Solution for EE Kit • Redesign courses based on online course template • Redesign class schedule • Redesign assignments due dates • Redesign assignments weekly workload • Redesign faculty' office hours
understand the enterprise context	• Unify curriculum for both ground campus and online campus • Unify the Interface of LMS for both ground and online students
integrate systems engineering and project management	• Integrate school library with LMS • Integrate Interface to advisors with LMS • Integrate course development and course publishing with LMS • Integrate IT Support with LMS • Integrate Messenger with LMS
invest in the early stages of projects	• Leverage existing LMS • Leverage existing online course template • Leverage purchase process for EE Kit purchase

The next step is to address the issues that are the most critical in order to allow students' learning experience not damaged, and enable the BSCE degree program continuously achieving its learning objectives regardless of which learning platform and modality. We have identified the functionality that can balance out the negative impacts to students learning and realizing the learning objectives of the BSCE degree program, and that we must provide these functionalities with priority. We call these functionalities as "fundamental OLE enablers".

The first example is to resolve the challenge of allowing students to conduct their Electrical and Electronic Engineering (EE) hands-on lab assignments in an OLE. There are two possible solutions to allow students to continue conduct Electrical Engineering hands-on labs in an online learning environment. The first option is to have centralized simulation software that allows multiple students concurrently access and conduct the labs assignments via simulations (e.g., via PSpice, MATLAB, etc.). The second option is to provide each student an EE Kit which contains the soldering tools, various electronic components or parts, electronic circuit interconnecting breadboards and wires, as well as the software which can convert a PC, via analog-digital conversion, into virtual instruments such as an electrical measurement meter, a signal generator, an oscilloscope, etc.. This EE Kit enables students to perform almost all the hands-on labs assignments at their own home. We can also consider the second option as the distributed solution. After comparing these two options, we decided to adopt the second option. The main device in the EE Kit is called myDAQ, supplied by National Instruments, which provides combinations of analog I/O, digital I/O, and counter/timer functionality in a single device for computer-based systems. We can use this EE Kit for six of the EE courses in our BSCE degree program. In this way, students can conduct the EE hands-on assignments at home, and post the results of the experiments made by them in the online learning management system, and graded by the course instructor.

When the ground campuses closed due to COVID-19 pandemic, students cannot access campus-based EE labs anymore, which is the biggest risk for us to achieve the program outcomes of BSCE degree program. By choosing the EE Kit with myDAQ devices, we have effectively mitigated this risk. Borrowing the concepts of system engineering management, we have balanced out the instability caused by losing on-ground EE Labs in the online learning environment by now using the EE Kit with myDAQ devices.

The online learning environment plus student's homes formed a closed-loop system that provides all the services available in the ground campus' learning environment. That is the distributed OLE, which consists of the OLE plus the homes of all students and can become a stable replacement for the traditional ground campus' learning environment.

Another example is to extend the functionality of an OLE such that the OLE can provide students and faculty the convenience of accessing commonly used services similar to what the traditional ground campuses can offer. The OLE has not only the virtual classrooms, where students can access multiple classes for the learning materials, submit assignments, as well as conduct discussions with faculty and classmates, but also access various services such as Library, IT support, Students Advisor, Finance, Registrar Office, etc. via the web-links. This enhanced OLE functionality has further increased the stickiness of faculty and students with an OLE, which has helped the stability of an OLE.

The third example is introducing the usage of instant messenger in an OLE. To enhance the engagement between either faculty and students, or students and students, an instant messenger system, which has integrated both mobile devices and personal computers, has been launched for students and faculty to use. Meanwhile, the data reports are also generated

based on the messenger usage data so that faculty and academic administrative staff can quickly notice the common issues that students experience on the courses that they are taking, so that a solution to address the issue most of time can be delivered much faster. These enhanced capabilities of an OLE have made students much easier to adapt to the online modality and become more and more addicted to an OLE. In another word, an OLE used to support BSCE degree program can satisfy all common needs of students, faculty and administrative staff, so that the entire system can run very smoothly.

B. *Use Cases of Applying Various Learning Padegages*

1) *Use Case 1: Applying Experiential Learning*

We strongly believe that applying experiential learning is critical for BSCE students. Therefore, we have to provide students with capabilities to do their hands-on EE lab assignments in either asynchronous mode, in which the faculty will not be preset, or in a synchronous mode, in which both faculty and students can see each other through a zoom link, and the faculty can observe the student's execution of the hands-on EE lab assignment. The students and faculty can communicate via zoom voice channel as they can see each other via the zoom video channel. In fact, one faculty can also do the similar service in "one to multiple" fashion, so that one faculty can observe multiple students EE labs hands-on work concurrently. By using such setup, plus properly scheduling, conducting EE hands-on labs assignments have become very easy, so that we rarely hear complaints on the EE hands-on Labs assignments in the online modality.

In either mode, students will take the screenshots for the results of their hands-on EE Labs assignment, embed these screenshots into the written experiment report, and then submit the report to their faculty for review and grading. Sometimes, faculty also asks students to share their reposts to the classmates for mutual review and feedback.

2) *Use Case 2: Applying Adaptive Learning*

One of advantage of the virtual classroom on an OLE over ground campus classroom is that students can take the class, i.e., observe the recorded lectures, at anytime and anywhere. During the pandemic, a student or student's family member could have caught the virus. In such situation, the patient will be sent to a hospital or stay at home to be quarantined for at least two weeks. If students take classes in a ground campus, he/she will certainly miss the classes in such situation. In the online-modality, as all students are taking their classes through the virtual classrooms on an OLE, when the students get COVID-19, none of them has missed any class. There is another reason for students' success in such difficult time: it is that we have used a courseware called Intellipath, which is a software tool capable of supporting adaptive learning pedagogy in many BSCE courses. In Intellipath-based courses, each student's study load is customized based on individual student's existing knowledge and foundation related to the course subject, so that some students can leverage their existing knowledge on the course subjects to accelerate their learning.

3) *Use Case 3: Applying Competency-based Learning*

Another learning pedagogy that we have applied is the competency-based learning. In some of the online BSCE courses, we have designed some of the individual projects to have clear requirements on the result but no any specific restriction on the methods and processes that can be used. We have advised students to reach-out to their faculty if they would like to discuss their ideas or plans for their projects via either email or instant messenger. In those courses, the mobile and PC integrated messenger system has become an effective engagement channel between faculty and students. Our research has discovered that students' learning experiences have been continually improving based on the end-of-class student survey data, the class-grade-distribution data, and the class completion rate.

4) *Use Case 4: Applying Continuous Assessment*

In contrast to the traditional assessment format used in ground campus based learning environment, where exams and/or quizzes are the main forms of assessment, for all online BSCE courses, we have adopted a continuous assessment mechanism. In this assessment, many types of student learning activities, such as discussions (in discussion-boards), course assignments, individual project, group projects, presentations, etc. all can be assessed against the courses' learning objectives and/or program outcomes. Because in an OLE students' activities within the OLE can be recorded, the artifacts that can be used for assessments are therefore easily collected and available. Meanwhile, most of the software tools that we have used to support various learning pedagogies have already supported continuous assessment.

V. CONCLUSION

Among all the degree programs involving technical subjects, engineering degree programs are the least available online. The main challenge for moving an engineering degree program to online modality is the hands-on labs associated with any engineering degree program. In this study, we have shared our practice of migrating the curriculum of BSCE degree program, which is a ground campus only originally, to include the online modality. In this paper, we have described how we applied the principles of system engineering management, and the various learning pedagogies to address a few of the typical challenges commonly occurring in the process of migrating a ground campus only BSCE degree program to the online modality. So far, we have successfully launched online BSCE degree program. We have implemented all the strategies that we have discussed in this paper. Based on all the above, we can claim that we have provided the positive answer to our research questions.

The future works include collecting class performance data and student artifacts from the BSCE courses that have already run in an OLE to conduct assessment based on the predefined assessment rubrics, which reflects both the courses' learning objectives and/or program outcomes, and analyzing the assessment results so that we can not only find the room for further improvement.

ACKNOWLEDGMENT

We sincerely thank the reviewers who have not only confirmed the importance of our research work, but also provided us some recommendations to further improve the quality of this paper.

REFERENCES

[1] Park JJ, Park M, Jackson K, Vanhoy G. Remote Engineering Education under COVID-19 Pandemic Environment. International Journal of Multidisciplinary Perspectives in Higher Education. 2020;5(1):160-6.

[2] Daniel SJ. Education and the COVID-19 pandemic. Prospects. 2020 Oct;49(1):91-6.

[3] Bozkurt A, Jung I, Xiao J, Vladimirschi V, Schuwer R, Egorov G, Lambert S, Al-Freih M, Pete J, Olcott Jr D, Rodes V. A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. Asian Journal of Distance Education. 2020 Jun 6;15(1):1-26.

[4] Taghizade, A., Hatami, J., Noroozi, O., Farrokhnia, M., & Hassanzadeh, A. (2020). Fostering learners' perceived presence and high-level learning outcomes in online learning environments. *Education Research International, 2020*http://dx.doi.org/10.1155/2020/6026231.

[5] O' Shea, S., Stone, C., & Delahunty, J. (2015). "I 'feel' like I am at university even though I am online." Exploring how students narrate their engagement with higher education institutions in an online learning environment. Distance Education, 36(1), 41–58. https://doi-org.coloradotech.idm.oclc.org/10.1080/01587919.2015.1019970.

[6] Alqurashi, E. (2019). Predicting student satisfaction and perceived learning within online learning environments. Distance Education, 40(1), 133–148.https://doi-org.coloradotech.idm.oclc.org/10.1080/01587919.2018.1553562.

[7] Roshni, S., & Quek Choon, L. G. (2020). A case study investigating programming students' peer review of codes and their perceptions of the online learning environment. Education and Information Technologies, 25(5), 3553-3575. http://dx.doi.org/10.1007/s10639-020-10111-9.

[8] LAMANAUSKAS, V., MAKARSKAITĖ-PETKEVIČIENĖ, R., GORGHIU, G., SANTI, E.-A., & PRIBEANU, C. (2021). Exploring the Students' Perceived Academic Value in an Exclusive Online Learning Environment. Romanian Journal for Multidimensional Education / Revista Romaneasca Pentru Educatie Multidimensionala, 13(4), 1–16. https://doi-org.coloradotech.idm.oclc.org/10.18662/rrem/13.4/467.

[9] Guasch, T., Espasa, A., & Martinez-Melo, M. (2019). The art of questioning in online learning environments: the potentialities of feedback in writing. Assessment & Evaluation in Higher Education, 44(1), 111–123. https://doi-org.coloradotech.idm.oclc.org/10.1080/02602938.2018.1479373.

[10] T. H. Morris, "Experiential learning–a systematic review and revision of Kolb's model." *Interactive Learning Environments* Vol.28, Issue 8: pp.1064-1077, Jan. 2019.

[11] J. Dewey, "Experience and education". New York: MacMillan, 1938.

[12] L. Joplin, "On defining experiential education". In K. Warren, M. Sakofs&J. Kielsmeier (Eds.), the theory of experiential education. Dubuque, IA: Kendall-Hunt, 1995, pp. 22-29.

[13] Y. Cao and H. Liu, "Study of Experiential Learning as a Model for Teaching and Learning", in Proceedings of 2009 Second International Symposium on Knowledge Acquisition and Modeling, Vol. 2, Nov.30 – Dec. 1, 2009, Wuhan, China, pp.391-394

[14] S. K. Chiu, "Innovative experiential learning experience: Pedagogical adopting Kolb's learning cycle at higher education in Hong Kong", *Cogent Education*, Vol. 6, no. 1, p.1644720, July 2019. DOI: 10.1080/2331186X.2019.1644720

[15] B. Kehrwald, "Understanding social presence in text-based online learning environments," Distance Education, vol. 29, no. 1, pp. 89–106, 2008.

[16] J. Gervais, "The operational definition of competency-based education", The Journal of Competency-Based Education. **1** (2): pp. 98–106, 2016.

[17] S. Kopeinnik, et al, "Combining Self-regulation and Competence-based Guidance to Personalise the Learning Experience in Moodle", in Proceedings of 2014 IEEE 14th International Conference on Advanced Learning Technologies", July 7-10, 2014, , Athens, Greece, pp.62-64.

[18] D. Johnson and D. Samora, "The Potential Transformation Of Higher Education Through Computer-Based Adaptive Learning Systems," Global Education Journal, vol. 1, 2016.

[19] "APLU Awarded $4.6 Million to Advance Personalized Learning and Proactive Advising at Public Universities," http://www.aplu.org/news-and-media/News/aplu-awarded-46-million-to-advance-personalized-learning, Retrieved: 2019-03-15.

[20] C. D. Dziuban, P. D. Moskal, J. Cassisi, and A. Fawcett, "Adaptive Learning in Psychology: Wayfinding in the Digital Age," Online Learning, vol. 20, no. 3, pp. 74-96, 2016.

[21] C. Howlin and L. Danny, "A framework for the delivery of personalized adaptive content," 2014 International Conference on Web and Open Access to Learning (ICWOAL), IEEE, pp. 1-5, 2014.

[22] C. Farr, "Cerego finally launches its 'Dropbox for the brain'," https://venturebeat.com/2012/12/10/get-smarter-cerego-finally-launches-its-dropbox-for-the-brain, 2012, Retrieved: 2019-03-15.

[23] Sue. Shellenbarger, "Flashcards Get Smarter So You Can, Too," Wall Street Journal, 2015, Retrieved: 2019-03-10.

[24] Q, Sun, Y. Abdourazakou, and T. J. Norman, "LearnSmart, adaptive teaching, and student learning effectiveness: An empirical investigation," Journal of Education for Business, vol. 92, no. 1, pp. 36-43, 2017.

[25] B. R. Crisp, "Is it worth the effort? How feedback influences students' subsequent submission of assessable work", *Assessment & Evaluation in Higher Education* vol. 32, no. 5, October 2007, pp. 571-581.

[26] R. Ghiatău, G. Diac, and V. Curelaru, "Interaction between summative and formative in higher education assessment: students' perception", *Social and Behavioral Sciences* vol. 11, 2011, pp. 220–224

[27] K. A. Gary and S. Xavier, "Agile Learning Through Continuous Assessment", in Proceedings of 2015 IEEE Frontiers in Education Conference (FIE), Oct. 21-24, 2015, El Paso, Texas, USA, pp. 1-4

[28] NASA Consortium. Engineering Elegant Systems: Theory of Systems Engineering (Fourth Draft), 2018

[29] Emes*, Michael R., et al. "8.1. 2 Principles of Systems Engineering Management: Reflections from 45 years of spacecraft technology research and development at the Mullard Space Science Laboratory." INCOSE International Symposium. Vol. 22. No. 1. 2012.