Matched Assessment Data Set for Experiment-Centric Pedagogy Implementation in 13 HBCU ECE Programs

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Abstract
This paper continues the investigation of findings from a multi-year project that is initiating technology supported experimental centric approaches to learning in electrical and computer engineering courses at 13 historically Black colleges and universities (HBCUs). One of the personal instrumentation tools supporting experimental student-centered learning at these institutions is the Analog Discovery Boards (ADBs). The content or setting of use reflects introductory, circuits, and supporting electrical and computer engineering courses. The students consisted of undergraduates enrolled in engineering courses across the 13 member institutions. The authors provide an overview of learning theories that support experiential learning, followed by brief overviews of selected validated instructional modules that utilize experiential learning in engineering classes (modules will range from introductory to senior project use). Evidence-based outcomes related to students are presented that document the impact on the selected student outcomes. The findings also include catalysts and barriers to implementation and potential needs for sustainability.

Keywords
Experiential learning, hands-on instrumentation and experiments, hand-held mobile devices

Introduction

Today students learn differently from 20th century students. Traditional methods of teaching that involve passive approaches to learning are no longer effective. The students want strategies that include experimental learning, learning communities and visual stimulation[1]. Active learning theories provide the foundation needed to change teaching in higher education[2,3]. The use of technology has been shown to contribute to learning and knowledge retention[4-6]. Student centered active learning approaches coupled with educational technology have "significantly better learning outcomes than the traditional lecture/recitation approach" [7, 8].

There is a great need for reform in the higher education in the STEM fields. K-12 STEM students enter college with experience with hands-on technology, and active learning approaches. Individual or a group of STEM students may learn with technology embedded with simulated outcomes and real life experience [9]. Rodd and Newman[10] have shown that higher education students with technology reinforced learning have positive attitude towards learning and retention of the subject content.

Several hands-on learning models for engineering education have been reported [11, 12]. The Mobile Studio has been shown to support experiential learning by providing hands-on experience for students. The technology, when coupled with discovery learning, has been reported to promote problem solving, and information transfer in content related to physics and electrical engineering [13, 14]. There is very little work that shows that experimental-based learning is successful for students of color[14]. There is a need to determine if hands-on learning will be successful for students of color. The literature shows that many students of color are not entering the STEM fields or leaving the STEM majors due to instructional practices not suited to their needs or the perception that the STEM field is not related to real world [15, 16]. One way of solving this problem is the use the experiential-based learning.

In 2013, Howard University, in collaboration with Alabama A&M University, Florida A&M University, Hampton University, Jackson State University, Morgan State University, Norfolk State University, North Carolina A&T State University, Prairie View A&M University, Southern University, Tennessee State University, Tuskegee University, and University of Maryland Eastern Shore, received a National Science Foundation (NSF) grant entitled, *Experimental Centric Based Engineering Curriculum for HBCUs*." The project discussed in this research study which was conducted through the NSF grant support was undergirded by several theoretical and analytical frameworks that support project-based, experiential-based, and technologically-based learning experiences in higher education settings and science, technology, engineering, and mathematics programs. The purpose of this research study was to examine the impact of using experiential learning strategies and ADBs in student learning activities in electrical engineering courses in HBCU ECP collaborative schools. Analog Discovery Boards are portable devices that are designed to take electronic measurements similar to those benchtop electronics laboratory equipment. They provide more options for students as they can also use the devices outside of the classroom setting. The ADBs were used as supporting tools for traditional electrical engineering classes, but did not supplant the use of traditional laboratory equipment. This paper does not compare the uses of ADBs and circuit simulators for facilitating hands-on learning.

Background of the Study

This research study provides a cumulative review of the effects of a grant-funded experiential-based learning curriculum in engineering programs at 13 HBCUs in the United States. In this study, the researchers examined the overall impact of the program by assessing the matched data from the initial pre-surveys of students enrolled in the 11 of the 13 HBCUs where research was completed at the beginning of the fall 2015 and spring 2016 semesters and the final post-surveys assessing their understanding of the project and electrical engineering concepts at the end of fall 2015 and spring 2016 semesters. The goal of the NSF-funded project was to increase the number of highly qualified and prepared engineering students, particularly African American engineers, as well as to ensure electrical engineering students and graduates have a better understanding of technology and its role in STEM education and the policy associated with it. Another key goal of the project was to promote wide spread dissemination and usage of portable hands-on portable devices through proactive collaboration between educational institutions using a pedagogical model for classroom instruction that combines blended-learning approaches i.e. combinations of lecture and hands-on activities in class; traditional hands-on activities completed outside of class time, etc.).

Method and Data Sources

In this paper, the authors present validated modules which integrate the ADBs into experimental teaching and learning settings. The researchers collected data for two semesters (fall 2015 and spring 2016; Academic Year 2015-2016) with a cadre of instructors experienced in the use of both the ADBs and experimental approaches. These findings present the latest data regarding the effectiveness of ECP. The researchers desire to capture longitudinal data about the effectiveness of the experimental centric curriculum as well as the effectiveness of using ADBs. This paper continues the series of research studies to examine the effectiveness of both with a different cohort of students. This research continues the body of work and knowledge on experiential learning and usage of mobile devices in electrical engineering programs.

The variables of interest in the longitudinal study included: (a) effect of pre-requisites of learning (attitude, motivation, interest in learning engineering), (b) immediate affective outcomes of learning (impact on recall, use for in-course problem solving, and module specific knowledge), and (c) potential impact on long-term outcomes (transfer of skills to new content, new settings, and retention of problem solving skills). In addition, the researchers tracked a series of selected (Accreditation Board for Engineering and Technology) ABET indicators, via self-report, pre to post.

Data sources for this report include 408 matched pre and post student surveys from 11 institutions supported by 13 site visits, 15+ external observations of student use in the classrooms and labs, and over 75 interviews with administrators, faculty/instructors and students. As part of this evaluation effort, the researchers collected pre-affective surveys from students prior to classroom use (overall Pre-N=697, Fall pre-n=376, Spring pre-n=321); students completed post-test surveys at the end of ADB use each semester (overall Post-N=583, Fall 2015post-n=310, Spring 2016 post-n=273). A comparison of pre and post student buffer identification codes yielded a validated, matched data set of 408 responses--70% of post responses (Fall matched n=260, 84% of post responses; Spring matched n= 148, 54% of post responses).

Results and Findings

Participant Demographic Information

Although there were a total of 13 institutions involved in the ECP Project, the researchers are only reporting data from the 11 institutions who submitted and participated in the pre and post survey data collection. Of the 11 institutions, the majority of the students, 72%, were male and 28% were female. Regarding race/ethnicity, 85% of the respondents self-reported the race/ethnicity as Black, 4% as Hispanic, and 9% as multi-racial; 7% as Asian and 9% as White. Of the students involved, 16% indicated that English was not their primary language. The majority of the students were 2nd year (27%) or 3rd year (42%) higher education students; 67% of the enrollees were majoring in electrical engineering; 23% self-reported as computer science or mechanical engineering majors. The remaining students generally reported majors related to other STEM domains for which the course served as an elective or to fulfil a minor requirement (see Table 1).

Table 1
Student Demographics*

Gender	Gender %	Discipline of Study	Major
Male	72	Electrical	67
Female	28	Computer Science	19
Ethnicity	**Ethnicity**	Mech Engineering	4
Black	72	Other**	4
White	9	**Degree Progress**	**Degree**
Multi-racial	9	Year 1	14
Asian	7	Year 2	27
Hispanic	4	Year 3	42
English Primary	**Language**	Year 4	13
Yes	84	Graduates, Year 5	4
No	16		

**Matched Data Set N=408 based on posted data responses*
*** Chemical Engineering, Civil, STEM, Business, other*

There were six major findings related to the matched data sets regarding the usage of experiential learning and ADBs in electrical engineering courses. In the following narratives, the researchers discuss the overall major findings as well as provide the supporting data.

Finding 1. Variety of Usage in Instructional Settings.
Participants who accessed the ADB in all engineering classes using *experimental-centric pedagogy supported by ADBs completed activities in a variety of instructional settings and content domains throughout the 11 universities and colleges involved in the data collection for the research study.* Verification and validation of ADBs as a tool to support experimental centric learning practices within engineering classes was based on instructor description, student identification and evaluator observations. The most frequently occurring *location or setting of use* identified was traditional classrooms (e.g., the focus is on imparting theory, the instructor has an active teaching role), lab settings (e.g., the focus is on practice or use of theory, the role of the student is active), and as part of assigned homework (e.g. as a result of either classroom or lab instruction, students are required to do "out of setting" graded learning exercises); additional settings identified through in-depth analysis included classrooms that emphasized a studio approach to learning; that is, students were actively involved in experimentation in a theory based classroom, and individual project use, generally conducted by upper level students[17].

Finding: 2. Instructional Use: Application of the ADBs

Use of the ADBs, as a tool to support experimental centric learning practices within engineering classes was shown to be successful across a variety of instructional settings and through a mixture of different instructional uses which varied across the course in which it was used. The median for typical student usage of the ADBs was 3-5 times per semester within the classroom setting; 3-5 times per semester within lab settings was; and 1-2 times per semester for assigned homework. These results represented a skewed distribution with 31% of students experiencing six or more uses in a classroom setting, 50% reporting six or more uses, and 31% six or more times for homework assignments. Further reviews indicated overlapping or simultaneous use of the ADBs varied by institution. Preliminary correlations of use indicated that higher use was positively related to higher outcomes[17]. Students reported a median independent use of 3-5 times a term; overall, 37% reported at least 6+ times of independent uses per semester. This independent use, conducted without instructor or TA assistance was conducted either by individuals or by small groups (see Table 2).

Table 2
Pre and Post Use of ADBs in Varied Instructional Modalities

Instructional Modality	Pre		Post	
	Median Response	**% Used 6+ times**	**Median Response**	**% Used 6 + times**
Location/Setting of Use*				
In a class setting	Never	14	3 times	31
In a lab setting	Never	22	3 times	50
As part of homework assignment	Never	18	3-4 times	31
Method of Use*				
Instructor Demonstration	Never	15	3-4 times	33
Cooperatively with a peer	Never	24	3 times	53
Independently	Never	18	5 times	37

** Multiple responses allowed*

Similar to year two findings, new use was reported primarily within the laboratory setting and reflected supplemental/substitutional use for prior lab experiments. In the lab settings, use was part of a typical experimental effort with standard reports generated to support use. The instructor for these lab uses frequently was not the theoretical course instructor and teaching assistants' (TAs) usage varied on degree of experience with the ADBs and experimental centric instruction. In some settings, the TA had prior experience with the ADBs and independently developed manuals, experiments, and "tinkering" exercises. In expansion settings (e.g., either new courses or new modules, or modified instruction that reflected experimental pedagogy), the instructor usually had prior experience with the ADBs and was modifying instructional practices and curricula. It was noted, however, that in all lab settings, students reported a need to have lab use tied back to traditional course content if the use was not correlated by faculty. In these cases, students desired that the course instructor provide more "real world" application, and that practical lab use integrate theory and practice.

Use as independent homework, outside structured lab/classroom settings, was designed to support both traditional class instruction and lab work. In new-use settings, this homework often was for extra credit or exploratory purposes and was an extension of regularly assigned work. As use became more embedded and the instructor(s) more familiar, inclusion in homework reflected advanced opportunities to practice/learn material. As noted above, this expansion included applications in new courses, but more often was to new modules within courses already using the ADB.

The *method of use* also varied by site and was found within each of the settings. The key methods of use included instructor demonstration (e.g., instructor shows students how to use the ADB and potential results, students are passively watching), cooperative use with a peer (e.g. active use by the student with another student; the instructor is available for assistance), and independent use (e.g. the student alone or with other students work without instructor supervision, the content may be assigned or voluntary). Secondary analysis[17] revealed two types of instructor demonstration; the first exemplified demonstration of the tool and direct theoretical examples; the second used demonstration emphasizing real practice that embedded theory into real-world problem solving. This latter form of instructor demonstration/real world use was related to higher affective outcomes.

Cooperative use, described by instructors and TAs, and observed by evaluators, usually reflected dyad and triad exploration, most frequently in a structured-goal based setting. This occurred in both classroom and lab settings. Typical students experienced this type of use 6-9 times per term (median use).

Finding 3. **Use of ADBs in Varied Instructional Modalities**

Participants reported general satisfaction with and positive perceptions of the hands- on- experiences that were used to support learning; faculty reported increased comfort level with the new pedagogy and students evidenced increased outcomes as faculty became more comfortable. Participating students reported use of hands-on learning to be a positive experience (see Table 3). Most of the students (76%) agreed that use of the ADBs allowed them to practice course content, viewed this practices as relevant to learning (81%), reflecting of course content (80%), and real world practice (77%).

Table 3
Student Perceptions of the Process of Use

Instruction and Supplementary Materials*	**Matched**
	%*
The AD board provided opportunities to practice content	86
The use of the AD board reflected course content	80
Use was relevant to my academic area.	81
The use of the ADB reflected real practice.	77
The time allotted for ADB use was adequate.	76
The use of ADB suited my learning needs.	77
Introduction to the AD Board/Supplemental Materials	**%***
Instructions on ADB use were relevant.	73
Instructions on ADB use were helpful.	72
Handouts necessary for ADB use were provided.	72
The visual aids (e.g. diagrams) used with the ADB were clear and helpful	69

**Number represents percentage of participants who responded "Strongly Agree"/"Agree"*

Overall, the students noted the hands-on use reflected their learning needs (77%) and approved of the opportunity to practice their content (76%). Students commented on the value of this process with sentiments such as "*it helped me to understand how some things that I only have theoretical knowledge of*" and "it *helped me translate the written word to reality*."

A majority of the students also reported general satisfaction with instructions and supplemental materials used to support the above uses. In-depth analysis identified that satisfaction with use and perceptions of positive outcomes increased as instructor familiarity with the ADBs and experimental pedagogy increased. As noted in previous reports [17,18], first time student users and novice instructors indicated a need for more introductory materials, videos, and visual aids that would facilitate use.

Several schools reported developing site and content specific videos and introductory materials that helped students become familiar with start-up use. Several sites also reported that 4th year students were involved with this development. Triangulation of survey, interview, and observations data found that as faculty became more experienced with use, first time student users reported fewer difficulties and, while still desiring introductory materials, reported fewer difficulties in initiating use.

Finding 4. Use of ECP and Increases in Pre-requisites to Learning

Use of experimental centric pedagogy, supported through use of the ADBs, contributed to increases in known pre-requisites to learning. Students' pre-learning outcomes, their confidence in ability to learn, their motivation to learn content, and their perception of importance of learning helped foster confidence in knowledge gains. Faculty also noted these shifts in learning patterns, especially among students enrolled in introductory courses.

Multiple domains of short-term learning known to influence constructivist-based experiential learning were shown to be supported by use of the ADBs when embedded within hands-on learning. These included pre-requisite affective changes needed for learning to occur. Approximately three out of four students reported changes relative to attention of/to the need to learn, as reflected by growing perceptions of importance of knowledge of the ADB in preparing to become an engineer (81%), followed by increased motivation (73%) to learn the content supported by a growing confidence (75%) in learning/working in the content (see Table 4).

Correlated to these changes is a perception that knowledge had increased (84%), which in turn reinforced attention, motivation and confidence in learning, creating an increasingly positive cycle of affective support.

When queried as to how experiential hands-on pedagogy helped them learn, 83% reported that use of the ADBs was key to the increase. Actions related to affective pre-requisites included helping students develop interest (75%), become motivated to learn content (77%), become confident in learning course content (79%) and more specifically, become confident in completing lab assignments (69%).

Table 4
Initial Changes Reported by Students

	Perceived Changes	% *
Immediate Learning	My knowledge has increased as a result of use	84
Pre-requisite to Learning	The hands-on ADB is important in my preparation as an engineer	81
Pre-requisite to Learning	My confidence in the content area has increased because of use	75
Pre-requisite to Learning	Using the ADB motivated me to learn the content	73

**Number represents percentage of participants who responded "Strongly Agree"/"Agree"*

Specific areas of learning noted included recalling course content (77%), learning about practical applications of AC/DC circuits (74%), thinking about problems in graphical/pictorial/practical ways (76%), and developing skills in problem solving within the content area (83%). These skills were reported by 77% of the students as helping to directly improve their grade. Further analysis of the data continued to indicate that as instructors became more experienced in use, student approval ratings increased. Additionally, as courses were more directly related to electrical engineering, students reported higher levels of approval (see Table 5).

Table 5
How the Method Helped Learning

	Areas of Growth	Matched %*
General Outcome	Helped me to learn more	83
Immediate Learning	Develop skills in problem solving in the content area.	83
Immediate Learning	Think about problems in graphical/pictorial or practical	76
Immediate Learning	Learn how AC and DC circuits are used in practical	74
Immediate Learning	Recall course content.	77
Immediate Learning	Improve grades	77
Pre-requisite to	Develop confidence in content area	79
Pre-requisite to	Become motivated to learn course content.	77
Pre-requisite to	Develop interest in the content area.	75
Pre-requisite to	Confidently complete lab assignments.	76

**Number represents percentage of participants who responded "Strongly Agree"/"Agree"*

Regarding changes in support of sustained learning, students self-reported improvements in working collaboratively with fellow students (83%), enhancing their professional abilities (79%), and developing attitudes of self-direction and self-responsibility (80%). Students also self-reported effects directly related to problem solving (80%) and transferring skills related to problem solving (73%). For example, according to one student *"It (the board) showed how resistors worked in real life not just in theory and motivated me to learn more."* This also included developing different ways to solve problems, being able to apply course content to new problems and transferring their knowledge and skills to problems outside the course (see Table 6).

Table 6
Initial Long-term Outcomes

General Effects of Use of the ADBs	**Matche d**
	%*
Work collaboratively with fellow students.	83
Develop different ways of solving problems	80
Develop attitudes of self-direction and self-	80
Enhanced my professional abilities	79
Apply course content to new problems.	76
Transfer knowledge/skills to problems outside the	73

**Number represents percentage of participants who responded "Strongly Agree"/"Agree"*

Finding 5. Long-term Outcomes: ABET Indicators

Participants identified tentative relationships between the use of hands-on pedagogy supported by the ADBs and ABET valued characteristics. Students evidenced increases in importance and preparedness as their exposure to practice and real world problems increased; faculty noted students' growing sense of need for collaborative practice and the importance of problem solving related to real-world issues.

As part of the documentation of student growth directly related to professional outcomes students were asked to respond to a selected series of ABET outcomes. Because of the relationship of affective pre-requisites and potential outcomes, students were asked to indicate the importance of learning each outcome and their preparedness in performing that outcome after exposure to and use of experimental centric learning via the ADBs. Results of this comparison indicate that at the end of their experience, approximately 50% percent of the students perceived the ABET tasks as very important to learn with approximately 35% reporting that they were very prepared to exhibit these skills. A positive relationship was tentatively identified between the use of hands-on pedagogy and these perceptions. Students who had more exposure indicated higher levels of importance of these skills and greater levels of preparation (see Table 7). General professional goals (e.g. knowledge of contemporary issues, ability to work with multi-disciplinary teams, and ability to communicate in public settings) were not viewed as important as course specific content. The reason why students may indicate lower rating of ABET outcomes is related to the level of the coursework. Students in earlier or initial coursework may respond differently than students in capstone or upper-level coursework.

Further examination of these data indicate that areas viewed as highest in importance reflect specific goals of experimental centric learning (e.g. designing experiments, analyzing data, solving specific problems, and directly applying scientific processes. Faculty and students typically viewed these skills as cross-course outcomes and were not always identified with specific content.

Table 7
ABET Outcomes All Post Data

General Effects after use of the ADBs	% Very Important	% Very Prepared
Ability to apply scientific knowledge to engineering tasks	55	31
Ability to design experiments	47	29
Ability to interpret data	51	35
Ability to design system, component, process to meet	51	33
Ability to function effectively on multi-disciplinary team	49	38
Ability to communicate effectively as a public speaker	45	33
Knowledge of contemporary issues	38	27

**Number represents percentage of participants who responded "Very Important" or "Very Prepared" on a 4 point scale*

Ratings on preparedness of these skills were found to consistently place below importance. The most notable of these responses was the need to have knowledge of contemporary issues; this skill was rated as least important and as lowest in preparation. This finding is counter to instructor comments that they frequently referred to "real world" applications, to students' comments that they wanted "real world" applications.

Finding 6. Benefits, Barriers, and Needs Related to Continued Use

Faculty, administrators, students, and local assessment personnel reported multiple benefits, barriers, and needs related to the use of experiential, hands-on, learning supported through the ADBs. Benefits included extended learning, more interest in the profession, easier access to "labs," and changes in problem-solving approaches. Needs included more and cheaper access to ADBs, more curricula, more opportunities to share techniques and approaches of pedagogy, and more support for educational change.

Benefits noted by participants (See Table 8) included increased knowledge and greater creativity resulting from hands-on use; increased confidence; and more real-world knowledge as theory is tied to practice. Both students and faculty noted the value added to learning when hands-on practice and the opportunity to play and practice were included and expanded. Students commented: "[The board] *allowed me the opportunity to apply the information provided in the course which then helped me to retain and better learn the information."*

Students, especially those in circuits and advanced classes, noted benefits accrued from working on real-world problems; lower level students, in introductory classes noted benefits related to increased interest in the profession and the role of engineering work in solving world problems. According to students, "[The Board] *allowed me to work independently, leading to self-reliance and direction"* and *"connected my knowledge to real world applications."* As faculty grew more experienced in Board use, they noted the flexibility of the ADBs and the applicability of experiential centric approaches in different instructional contexts and through the use of different

Table 8
Sustainability-Benefits, Barriers and Needs

	Student Responses	Faculty/TA Responses
Benefits	• Increased knowledge about circuits • Provided good visual representations • Facilitated hands-on experience • Visualization of real-world/practical applications • Allowed opportunity to "play" and "practice"	• Increased hands on opportunities transferred learning • Real world application increased motivation and transferability • Flexibility for use in different contexts • Allows the faculty member to try out different ways of teaching material
Barriers	• Partnership use—hard to use as homework when shared; one person tends to get most "access" when used in lab • Wanted to take home/opportunity to practice • First time use difficult • Not all students had a laptop/MAC issues	• Want at the beginning of class, want introductory materials so can spend more time teaching content • Application issues with Mac computers • Voltage issues • More examples • Need time to play and develop their own style of use
Suggestions for the Future	• Provide clearer instructions on the ADB • Require individual possession or a semester long checkout • Get it at the beginning of the semester • In-class demonstrations on how to use ADB for projects • Increase in-class use blended with lectures • Make it a part of the class • Make sure the TAs and faculty know how to use it • Tie use into Sr. Project, internship and future job possibilities	• Boards available prior to the beginning of the semester • Help in involving more faculty and content; courses rotate and want continuity • Professional development for themselves and colleagues • More devices for faculty and TAs • More modules; more specific use/assessment tie-in • Give the students more time to "play"

instructional modalities, commenting, " *All students should have one; they need to be able to take it home."* Barriers to either continued or expanded use included the need to provide one ADBs per student, availability of curriculum and resources that support full semester and take- home use; lack of introductory materials (videos, instructions, etc.); and equipment- specific limitations. Both faculty and students want more use across all levels of settings. Faculty stated that "It takes time to create modules, we need time to work on this together." Students in circuits-related and advanced classes "*wanted their own"* ADBs as a means of increasing their involvement in experiential centric practice; cooperative learning exercises were viewed even more favorably if each student had his/her own set of tools. Faculty wanted the resources needed to expand use throughout entire circuits' courses as well as curriculum that would support differentiated levels of learning.

All participants identified future needs to enhance sustainability. Students wanted more help in initial introductions to experimental centric approaches so that they would know what the goals were, what was expected of them, and why this approach was important. They also desired a cross match between experiences and skills that would be expected in classes, and real world professional ability.

Conclusions and Recommendations

Further research is needed on the flexibility of the method by faculty teaching style, specific course content, and long-term achievement outcomes. Curriculum modules using ADBs, developed under the purview of this project, are now being used in a variety of instructional settings and content domains throughout 13 universities and colleges involved in the HBCU grant. Preliminary data indicate that faculty and students are benefiting from the use of the ADBs. Students and faculty report increases in constructs reflecting required affective pre-requisites to sustained learning; this includes interest in content, motivation to learn, and confidence in ability to learn. Through this project, use of the ADBs, as a tool to support experimental centric learning practices within engineering classes continues to be successful across a variety of instructional settings and through a mixture of different instructional uses which vary across the course in which it was used.

The findings from the study provide evidence that use of hands-on, experimental learning supported by the mobile ADBs yields positive learning outcomes related to current knowledge and ability. Students reported general satisfaction with and positive perceptions of the hands-on-lab experiences, instructions and supplemental materials that were used to support their learning. Faculty also noted an increased comfort level with the pedagogy as their experience increases. Immediate outcomes, reported by students, and verified by faculty include gains in course specific content knowledge, ability to transfer information to new setting, better problem solving, and increased professional characteristics.

For future usage of the ADBs and experiential learning activities, the researchers noted a need to ensure: (a) more standardized approaches and expanded curriculum modules are developed, (b) use of the ADBs as a support for experimental centric learning to allow for more independent use both in the classroom and with homework, (c) integration of the approaches in both class and lab settings, and (d) inclusion of ADBs in course pre-requisites as well as follow up/advanced courses.

Overall, the use of experimental centric approaches to learning and teaching, supported by the ADBs, appears to offer a promising method of increasing and enhancing engineering classes, yielding future engineers prepared to meet the needs of a rapidly changing world.

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