Article

active learning in higher education

Active Learning in Higher Education
1–16

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Experiencing autonomous futures: Engaged learning with next generation technology

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Abstract

Digital software has been proliferating in the classroom, frequently replacing students' hands on experiences. This article reports on a study that tested how hands on experiences with physical emerging technology, namely personal robots, drones, cameras, and echo dots, may improve or impair student learning and enhance or diminish the classroom experience. This study examines the potential impact of hands on experiences on student knowledge, skills, and values regarding emerging technology in the context of a course that employed traditional learning, defined as theoretical applications of next generation technology, namely autonomous vehicles during the first half, and hands on experiences with physical emerging technologies related to domotics, during the second half. Using three diagnostics, tweets, reflections, and discussion posts, we suggest that hands on experiences allowed students to more easily identify potential challenges with, and reduced their fears regarding, emerging technology. Additionally, our findings suggest that traditional learning methods may decrease familiarity with most technologies, whereas hands on experiences increased familiarity. Hands on experiences also appear to reverse several other trends associated with traditional learning. Ultimately, given the proliferation of technologies in the modern world and the impacts of automation, hands on experiences may be even more valuable than expected to students as they enter the workforce.

Keywords

authentic, autonomous vehicles, domotics, emerging technology, experiential, learning

Traditional and hands on experience learning with technology

Learning with and about technology could be improved by delivering instruction based upon known educational theories including constructivism and information transfer. Constructivist theories argue that student learning is best improved when the students themselves are involved in their own education (Wilson, 2012) and when learning is centered around experience (Ertmer and Newby, 2013; Porcaro, 2011). Likely due to an increased use of classroom technology, educators appear to be shifting towards constructivism (Weegar and Pacis, 2012). Information transfer focuses on how skills learned in one domain can be applied to another subject. For instance, a student learning with computers may

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learn skills and techniques which they can then apply to learning with smartphones. Information transfer is especially relevant to how students apply what they learn in school to their future work (Eraut, 2004). The instructional methods introduced herein are related both educational theories.

Traditional learning methods include lectures, hypothetical thinking defined as thought experiments about future and real-world application of technologies, discussions, and critical thinking exercises (Al-Qahtani and Higgins, 2013). Critical thinking exercises in particular have a profound impact on a student's learning outcomes (Facione, 2011). However, learning can be further improved via nontraditional learning methods, especially in regard to technology (Alavi and Leidner, 2001; Lukman and Krajnc, 2012). Incorporating technology into the classroom may increase student engagement (Dommett, 2018; Fredricks et al., 2016). Research suggests that traditional learning methods such as reading literature and conducting thought experiments do improve a student's knowledge. However, experiential learning and technology-mediated learning may provide a more authentic and impactful learning experience (Alavi and Leidner, 2001; Law and Baer, 2020; Savage et al., 2015). Furthermore, incorporating technology in the classroom may improve social equity as socioeconomically disadvantaged students often face greater challenges in the workforce due to their lack of hands on experiences with technology (Relles and Tierney, 2013).

Education is rapidly adapting, as illustrated by the inclusion of social media components into courses (Kassens-Noor, 2012; Liu, 2010; Oliver and Herrington, 2003; Tess, 2013). Yet a gap still exists when attempting to educate students about emerging and next generation technologies, specifically, how to measure their learning outcomes; though there is evidence to suggest that learning with traditional technology is beneficial. Providing students with hands on experiences with technology allows them to increase both their knowledge and skills (Alavi and Leidner, 2001). Moreover, they allow students to develop key competencies that assist them when entering the workforce (Savage et al., 2015).

Universities are well aware of the new demands for learning with technology (Relles and Tierney, 2013). At the administrative level universities employ an abundance of technology that allows students to register for classes, access catalogs, and participate in online learning (Braxton et al., 2000; Diamond and Irwin, 2013; Relles and Tierney, 2013). Ultimately, these efforts increase students' social integration, overall learning experience, and ability to collaborate with their cohort (Braxton et al., 2000; Gusc and van Veen-Dirks, 2017; Veletsianos, 2012). However, due to the move towards online learning, hands on experiences with technology is often lacking in the classroom despite its potential to improve learning (Kolb and Kolb, 2005; Lukman and Krajnc, 2012). The inclusion of virtual laboratories (computer simulated or online laboratories) in some curricula attempts to simulate hands on experiences, but there is debate as to whether or not virtual hands on experiences is comparable to actual hands on experiences in terms of effectiveness (Ma and Nickerson, 2006).

Emerging physical technologies

A host of new technologies are emerging that could potentially improve student learning outcomes and also have real-world applications. Digital cameras and video recorders, auditory devices like the Amazon Echo or Google Home, smartphones, and their associated virtual assistants, drones, and personal robots all may benefit students in and out of the classroom (Cui and Wang, 2008; Davie and Hilber, 2018; Dizon, 2017; Lilly et al., 2004; Palaigeorgiou et al., 2017). Hands on experiences with these technologies in the classroom is lacking; not only are the technologies often expensive, they require that the instructors themselves be familiar with them (Cui and Wang, 2008; Keengwe et al., 2008; Lilly et al., 2004).

Many of these technologies have the potential to significantly benefit education. Digital cameras are now a standard part of life (La Vigne et al., 2011) and students are increasingly asked to record and edit video in the classroom (Lilly et al., 2004; Marsh et al., 2010). Many use smartphones and they are proving to be useful in the classroom, helping students increase productivity, vocabulary, and communication (Bromley, 2012; Fan and Yang, 2020). Virtual assistants are also widespread and are increasingly being used both in the classroom and in the workplace in fields like healthcare (Davie and Hilber, 2018; Sharmin et al., 2006). More expensive technologies, such as drones and personal robots, have not yet been as widely received as the technologies above, but they too may play a pivotal role (Al Amir et al., 2018; Clotet, 2016).

As students transition into the workforce, understanding the challenges and potential benefits of these technologies will become increasingly important. Moreover, students entering the workforce will be expected to implement or interface with these technologies (Hannay and Fretwell, 2011). Hands on experiences with technology greatly improves a student's knowledge, skills, and overall understanding of when, where, and how to use different technologies (Alavi and Leidner, 2001; Lukman and Krajnc, 2012; Savage et al., 2015), though some find no difference in learning with or without technology (Islim, 2018). Even more important is the fact that familiarity with emerging technology breeds trust (Shavit et al., 2016). Exposure to emerging technology within higher learning may better prepare students for the future of work.

Educating students using technology and how to measure progress

Online learning, learning with digital technologies, and the internet in general have greatly improved learning (Braxton et al., 2000; Gusc and van Veen-Dirks, 2017; Veletsianos, 2012). The integration of social networking is a new and beneficial teaching tool (Kassens-Noor, 2012; Liu, 2010; Oliver and Herrington, 2003; Tess, 2013). One platform, Twitter, is powerful in regard to participatory practices by promoting active learning by allowing students to share opinions, receive prompt feedback, have discussions with both professors and classmates, link to publications, and maintain journal entries (Gikas and Grant, 2013; Tess, 2013; Veletsianos, 2012).

The internet, however, is merely one of many technologies which have the potential to improve learning outcomes. Digital cameras allow students to take, share, and edit photos for their projects, in a way, bringing the outside world into the classroom (Lilly et al., 2004). Smartphones allow students to always be connected to their classes via email, reading instructions, watching lectures, translating texts, or even working on assignments (Cui and Wang, 2008). Auditory devices, such as the Amazon Echo, allow for better classroom management. They can provide quick access to internet searches, set timers, help facilitate a myriad of activities (Davie and Hilber, 2018), and even have the potential to help students learn new languages or sharpen existing skills (Dizon, 2017). Drone technology encourages student participation and critical thinking (Palaigeorgiou et al., 2017; Sattar et al., 2017), removes socioeconomic barriers to exploration of the world and could increase cultural understanding and promote interconnectivity (Palaigeorgiou et al., 2017). Personal robots, such as TEMI, are just now emerging as legitimately useful technologies; these robots can provide classrooms with a form of virtual presence. Moreover, although they are often touted as tools for elderly care, they have the potential to be similarly useful in the classroom, especially for the learning disabled (Clotet, 2016).

However, measuring student progress in learning with technology is understudied. Quantifying a student's knowledge, skills, and values surrounding emerging technologies may provide educators with better understanding as to which teaching methods are the most effective (Herrington et al., 2014; Rollins, 2017). Traditional teaching methods effectively educate students, to a degree, but non-traditional methods may be even more effective at preparing students for the future (Lukman and Krajnc, 2012). Hands on experiences with technology may be the key to improving learning outcomes and preparing students for the future of work. Work in this area might best be guided by the Technological, Pedagogical Content Knowledge (TPACK) framework, which seeks to help educators better teach students about technology, focusing on knowledge, skills, and values, and Chickering and Gamson's (1991) research, which focused on improving education via seven distinct principles: Encouraging contact between students and faculty, developing reciprocity and cooperation among students, using active learning techniques, providing prompt feedback, emphasizing time on task, communicating high expectations, and respecting diverse talents and ways of learning.

Relevance for the future in learning with technologies

Professionals of the future will be expected to understand the when, why, and how of emerging technologies; they will also be in charge of implementing these technologies in a timely and efficient manner (Hannay and Fretwell, 2011). These workers will likely be responsible for the bottom-up implementation of technology, and their employers will almost certainly prefer to hire those who are familiar with technology (Hannay and Fretwell, 2011). Graduates face an increasingly difficult job market, and hands on experiences with technology may give students an edge (Yizhong et al., 2017), particularly in the context of the rapid expansion of automation and its potential impact on the future of work (Arntz et al., 2017; Kassens-Noor and Hintze, 2020). Be they virtual assistants or personal robots, the impact that these technologies will have on the future will undoubtedly be important. We must adequately equip students with the ability to interface and work with these technologies.

The potential benefits of these technologies are clear. However, few studies that have examined the impact that hands on experiences have on students' knowledge of, skills working with, and values surrounding emerging technologies. Further, what is lacking is a clear methodology for measuring success as well as a more concise understanding of how exactly technology impacts learning.

Research methods

Participants

The study was conducted in a graduate-level course dedicated to autonomous futures and emerging technologies at a tier 1 research university in the United States. The class consisted of 17 students, though only 15 participated in the study. The majority (12) of participating students majored in civil and environmental engineering, and 3 in urban and regional planning. Classes began in August 2019 and concluded December 2019.

Design and procedure

The course covered two major topics via two different pedagogical approaches, as illustrated in Table 1: Autonomous vehicles were taught via hypothetical learning and domotics were taught via hands on experiences. Classes were 3 hours long, half of which was dedicated to lectures and discussions and during the other half students were given Twitter prompts to experience domotics or

Table 1. Course structure of autonomous futures.

Lecture held	via	Hypothetical learning	Hands on experiences learning
Semester / Each class		5 weeks after beginning of semester	5 weeks before end of semester
Technology topic		Autonomous vehicles	Domotics
Out of class (1½ hours)	Twitter	Ride traditional transportation including bus, car, bike, scooter means and envision/hypothesize about changes if vehicles were autonomous	Experiential learning with Temi, Drones, Echo, camera, Siri
In-class (1½ hours)	Person	Lectures and discussions	Lectures and discussions and demonstrations

traditional means of transportation—hypothesizing about autonomous capabilities. Thought experiments within the class included critical thinking exercises that present hypothetical scenarios in which technology may be of use, field trips, lectures, and discussions. It was not until the second half of the course that students were presented with technology as a means to provide hands on experiences.

Diagnostic

There were four data collection sources—a diagnostic tool, individual journals, Twitter responses, and discussion boards. Three times throughout the semester students completed a diagnostic to measure a variety of outcomes. Students took the first diagnostic (D1) before the course began to establish their baseline knowledge of autonomous vehicles and domotics prior to the course. The second diagnostic (D2) demonstrates the progress that students made in understanding after traditional learning methods. The last diagnostic (D3) demonstrates the total change in student knowledge, skills, and values over the course of the entire class. The potential impact of hypothetical learning methods can be observed by comparing D1 and D2, while the potential impact of hands on experiences can be observed by comparing D2 and D3.

The diagnostic measured students' conceptual understanding of emerging technologies, based upon the TPACK framework (Mishra et al., 2006, 2011). The diagnostic was divided into two sections: one for autonomous vehicles and the other for domotics. These sections were further divided into questions covering knowledge, skills, and values. Knowledge questions asked students about their assumptions regarding emerging technologies, including reasons for and against their implementation, challenges they expected to see regarding the technology's implementation, and knowledge of important assumptions from the literature. Skills questions asked students if they would recommend the technology in general (referred to as user penetration) and different scenarios in which they viewed the technology as applicable (referred to as scenario penetration). Value questions asked students about their likeliness to purchase, ride in, or interact with, and their overall familiarity with emerging technologies. In total, the diagnostic took approximately 70 minutes to complete and was delivered on paper during class time, with an instructor present to answer questions. The diagnostic was 18 pages long and contained 98 questions: eight knowledge, 59 skills, 12 value questions, and 19 questions pertaining to previous experience with technologies. Questions were variable, including multiple choice, rank order, Likert scales, check all that apply, and fill in the blank. Some questions applied skip-logic: if a student did not have experience with, or find a technology useful, they skipped subsequent questions regarding it. Students were also asked to provide their major, class status, gender, ethnicity, and overall GPA. There was no identifying information included, though students were asked to sign a consent form.

Journals, Twitter, and discussion boards

Students were asked to respond in 200 words to weekly journal prompts that directed them to become participant-observers of a technological culture in transition (Murchison, 2010). Students were asked to keep logs of their encounters and observations regarding humans on roads, sidewalks, and during commutes; they were then directed to go home and write about how technology could influence their life, or the lives of others, and whether or not they were for or against certain technologies. There were also eight discussion boards throughout the class in which students were asked questions regarding emerging technology. Additionally, students were asked to participate in a moving classroom experience using Twitter in which they were instructed to walk around designated locations, tweet about their observations, and apply concepts taught in class in response to prompts (Kassens-Noor, 2016). In total students tweeted 365 times.

Measures and analysis

Data from all diagnostics were entered into Qualtrics and then coded double-blind by hand. Open-ended questions were coded via an iterative coding process to identify keywords and sentiments. D1 received 18 responses, D2 received 16, and D3 received 17. One student responded only to D1 and one student responded only to D1 and D3. Their responses were stricken from the data. Thus, the analysis included 15 responses that were recorded for all three diagnostics.

The diagnostic measured changes in knowledge, skills, and values at three points in the semester. On each diagnostic, students were asked to list assumptions related to the literature and reasons to (or not to) adopt smart technology. To measure changes in knowledge over the duration of the course, we then examined changes in the total number of responses, the number of response categories, the average number of responses per student, and the top three responses. Skills questions asked students if they recommended the technology in general and, if so, whether they would recommend it under four different scenarios (“anywhere,” “any time,” “all day,” and “year round”). We used these data to measure two concepts: user penetration and scenario penetration. The former measures the number of students who would recommend a specific technology, while the latter measures, for students who would recommend the technology at all, the number of scenarios (out of a maximum of four) in which students would recommend it. Values were measured by averaging the responses form a series of Likert Scale questions that asked about the students’ likeliness to purchase or use technologies and their familiarity with the technology used in the classroom.

Results

After engaging in hands on experiences, students more easily identified challenges with emerging technology and sometimes reported decreased trust; often this represented a reversal of trends associated with traditional learning. After engaging in hands on experiences, students were more likely to identify reasons why autonomous vehicles should not be allowed and reported fewer reasons to allow them. For example, as illustrated in Table 2, when asked to give reasons why

Table 2. Total number of responses and coding categories for knowledge questions.

	D1	D2	% Change D1–D2	D3	% Change D2–D3	Total
Autonomous vehicles-reasons why decision-makers should allow						
Number of responses	65	65	0.0%	63	−3.1%	193
Number of response categories	24	25	4.2%	18	−28.0%	
Average responses per student	4.06	4.06	0.0%	3.94	−3.0%	
Autonomous vehicles-reasons why decisions-makers should not allow						
Number of responses	58	50	−13.8%	53	6.0%	161
Number of response categories	17	20	17.6%	22	10.0%	
Average responses per student	3.63	3.13	−13.8%	3.31	5.8%	
Autonomous vehicles-assumptions in current literature						
Number of responses	39	70	79.5%	69	−1.4%	178
Number of response categories	23	21	−8.7%	20	−4.8%	
Average responses per student	2.44	4.38	79.5%	4.31	−1.6%	
Autonomous vehicles-challenges of transitions						
Number of responses	63	65	3.2%	65	0.0%	193
Number of response categories	17	24	41.2%	23	−4.2%	
Average responses per student	3.94	4.06	3.0%	4.06	0.0%	
Domotics-reasons why decision-makers should allow						
Number of responses	49	49	0.0%	56	14.3%	154
Number of response categories	27	22	−18.5%	23	4.5%	
Average responses per student	3.06	3.06	0.0%	3.13	2.3%	
Domotics-reasons why decision-makers should not allow						
Number of responses	50	46	−8.0%	53	15.2%	149
Number of response categories	19	16	−15.8%	17	6.3%	
Average responses per student	2.63	2.88	9.5%	3.31	14.9%	
Domotics-assumptions in current literature						
Number of responses	31	49	58.1%	57	16.3%	137
Number of response categories	19	24	26.3%	20	−16.7%	
Average responses per student	1.94	3.06	57.7%	3.56	16.3%	
Domotics-challenges of transitions						
Number of responses	46	48	4.3%	59	22.9%	153
Number of response categories	22	27	22.7%	25	−7.4%	
Average responses per student	2.88	3.00	4.2%	3.69	23.0%	

autonomous vehicles should be allowed, students presented no change between before the course began (D1) and the progress in terms of understanding that students had made since then (D2). However, after hands on experiences students identified −3.0% fewer reasons why they should be allowed on roads, and 5.8% more reasons why they should not be allowed. Similarly, with domotics, although after hands on experiences we observed marginal increases in the number of reasons to allow the technology (2.3%), it considerably increased the number of reasons students found not to allow domotics technology (14.9%).

Most notably, hands on experiences allowed students to identify markedly more challenges associated with AI-enabled technology than traditional learning: 4.2% after traditional learning and 23% after hands on experiences (Table 2). This is illustrated by some of the students' Twitter posts. For example, one student highlighted the nuance required for effectively communicating with TEMI, tweeting that because the student was "being super polite when asking TEMI to do something,

Table 3. Top 3 most frequent category of responses for knowledge questions.

	D1	D2	% Change	D3	% Change	Total
Autonomous vehicles-reasons why decision-makers should allow						
Safety/Crashes	16	11	−31.3%	11	0.0%	38
Traffic Congestion/Time	12	9	−25.0%	15	66.7%	36
Environment	6	2	−66.7%	5	150.0%	13
Autonomous vehicles-reasons why decisions-makers should not allow						
Cybersecurity	4	7	75.0%	7	0.0%	18
Safety	4	4	0.0%	7	75.0%	15
Affordability	8	2	−75.0%	3	50.0%	13
Technology is not ready	13	0	−100.0%	0	0.0%	13
Autonomous vehicles-assumptions in current literature						
Safety/Crashes	8	13	62.5%	11	−15.4%	32
Traffic Congestion	2	11	450.0%	5	−54.5%	18
Ridesharing	0	6	–	6	0.0%	12
Autonomous vehicles-challenges of transitions						
Infrastructure	12	5	−58.3%	6	20.0%	23
Merge with existing traffic	9	1	−88.9%	9	800.0%	19
Affordability	5	7	40.0%	3	−57.1%	15
Safety	8	4	−50.0%	3	−25.0%	15
Domotics-reasons why decision-makers should allow						
Safety/Security	9	14	55.6%	14	0.0%	37
Convenient	1	3	200.0%	8	166.7%	12
Ease of use	9	0	−100.0%	1	–	10
Domotics-reasons why decisions-makers should not allow						
Security/Privacy	22	10	−54.5%	15	50.0%	47
Cybersecurity	0	17	–	13	−23.5%	30
Failure with technology	4	3	−25.0%	4	33.3%	11
Domotics-assumptions in current literature						
Impacts/Improve life	1	5	400.0%	7	40.0%	13
Acceptance	1	2	100.0%	9	350.0%	12
Technology	0	2	–	9	350.0%	11
Domotics-challenges of transitions						
Acceptance	4	1	−75.0%	13	1200.0%	18
Cost	5	2	−60.0%	5	150.0%	12
Adoption	0	12	–	0	−100.0%	12

TEMI doesn't recognize [the] command because it's not a direct command." Other students provided even harsher critique of the technology via Twitter: "TEMI doesn't easily recognize voices so it hasn't completed a command yet" and "Practicality and functionality of TEMI is in question, does not respond to work-related requests." These examples highlight the important role that hands on experiences plays in helping students to identify potential challenges with technology.

Students also more readily identified both challenges and benefits with emerging technology and showed a reduction in apprehension regarding the use of the technologies after hands on experiences. After traditional learning students reported fewer reasons to allow autonomous vehicles. For example, a student journaled their thought: "I would be against the introduction of autonomous vehicles because I believe they cannot perform completely safe yet." As illustrated in Table 3, mentions of safety decreased by −31.3%, congestion by −25%, and environmental benefits decreased by −66.7%. However, after hands on experiences this trend reversed, and students found 66.7% more reasons to allow autonomous vehicles because of congestion and 150.0% more because of environmental impacts.

However, this was not true in reference to the safety of autonomous vehicles. After traditional learning students reported no concern that autonomous vehicle technology was not ready. Interestingly, this did not change after hands on experiences. Notably, after traditional learning students concerns about autonomous vehicles merging with traffic dissipated. However, after hands on experiences these concerns increased by 800.0% (an increase from 1 to 9 responses), indicating that students had a better understanding of challenges after hands on experiences. Finally, concerns regarding the affordability of autonomous vehicles increased by 40.0% after traditional learning but fell again by −57.1% after hands on experiences.

In regard to domotics, traditional learning and hands on experiences also appear to be associated with opposite trends. After traditional learning students were less likely to report concerns regarding security/privacy issues and technological failure (−54.5% and −25%), as illustrated in Table 3. However, after hands on experiences these concerns returned (+50% and +33.3%) exemplified by a discussion board entry: "Data security and privacy is a concern, particularly how data may be released or used by companies." Notably, concerns with cybersecurity by 23.5% increased after hands on experiences. Hands on experiences also appear to be associated with a better understanding of the challenges of implementing AI-enabled technologies; after traditional learning concerns regarding cost and acceptance decreased by −60.0% and −75.0%, respectively, whereas after hands on experiences these concerns increased by 150.0% and 1200.0% (an increase of 1 to 13 responses), respectively (Table 3).

Traditional learning is associated with increases with trust in technology, willingness to recommend it, and the average number of scenarios in which users would recommend it. In contrast, hands on experiences are associated with a reversal of some of these trends. For example, as shown in Table 4, after traditional learning students' willingness to recommend buses increased by 15.4%, cars by 20.0%, and pods by 20%. Additionally, after traditional learning the number of scenarios students would recommend these autonomous technologies in increased by 36.3% for buses, 27.7% for cars, 25% for pods, and 40.6% for scooters. For example, the most liked tweet from a student riding on a city bus but pretending it was autonomous stated: "It's awesome to share (what would be) an autonomous bus with so many people. I love how smooth it was to get on the bus and payment was automatic." However, after hands on experiences recommendations and scenario applications decreased: students are less likely to recommend buses by −13.3% and cars by −16.7% and recommend buses (−13.3%), cars (−8.6%), and scooters (−11.1%) in fewer scenarios. These findings indicate greater familiarity with the potential appropriateness of these technologies after hands on experiences.

Other technologies also saw wavering trends between traditional learning and hands on experiences. Students found fewer applications for drones (−16%) after traditional learning, but this increased by 16.5% after hands on experiences, as shown in Table 4. Students were less likely to recommend TEMI after traditional learning by −28.6%, but this increased by 20.0% after hands on experiences. Students were less likely to find scenario applications for auditory devices after traditional learning by −13.3%, but again, this was reversed after hands on experiences and increased by 6.5%. Students were also able to identify more useful scenarios for visual devices after hands on experiences. All of which indicates better familiarity with these technologies after hands on experiences. This is also supported by students' responses on Twitter. When prompted to consider how to ease the transition to implementing new tech, one student tweeted "Have more devices

Table 4. Likelihood of overall recommendation and recommended operating scenarios from students.

Type of technology	Questions	D1	D2	% Change	D3	% Change
Buses	Number of students who recommend operation	13	15	15.4%	13	−13.3%
	Average number of hypothetical operating scenarios	2.15	2.93	36.3%	2.54	−13.3%
Cars	Number of students who recommend operation	5	6	20.0%	5	−16.7%
	Average number of hypothetical operating scenarios	3	3.83	27.7%	3.5	−8.6%
Pods	Number of students who recommend operation	5	6	20.0%	6	0.0%
	Average number of hypothetical operating scenarios	2.4	3	25.0%	3	0.0%
Scooters	Number of students who recommend operation	5	4	−20.0%	4	0.0%
	Average number of hypothetical operating scenarios	1.6	2.25	40.6%	2	−11.1%
Drones	Number of students who recommend operation	8	6	−25.0%	6	0.0%
	Average number of hypothetical operating scenarios	2.38	2	−16.0%	2.33	16.5%
TEMI	Number of students who recommend operation	7	5	−28.6%	6	20.0%
	Average number of hypothetical operating scenarios	1.86	2.6	39.8%	2.67	2.7%
Auditory Devices (SIRI and Echo Dot)	Number of students who recommend operation	5	8	60.0%	10	25.0%
	Average number of hypothetical operating scenarios	3.75	3.25	−13.3%	3.46	6.5%
Visual Devices (Cameras)	Number of students who recommend operation	8	8	0.0%	13	62.5%
	Average number of hypothetical operating scenarios	2.8	3.25	16.1%	3.9	20.0%

The average for hypothetical operating scenarios is calculated adding the total number of respondents that believed the technology should operate anytime, any day, anywhere, and for anyone and dividing it by the number of students who recommended operation for that technology.

available and let them [people] play with it. Familiarity helps transition." Another student tweeted "Forces me out of my tech comfort zone, life and learning skills!".

In regard to likeliness to purchase or interact with emerging technology, hands on experiences again reversed trends originating from traditional learning. Willingness to ride in an autonomous vehicle increased by 1.6% after traditional learning but reduced by −3.1% after hands on experiences; see Table 5. Students were −7% less likely to purchase an autonomous vehicle after traditional learning, but this declined even further (−31.5%) after hands on experiences. With domotics, students' likeliness to interact with (−3.3%), purchase (−19.7%), and feelings of security (−13.4%) all declined after traditional learning. However, after hands on experiences these numbers increased:

Table 5. How likely are students to interact or purchase technology.

Type of technology	Questions	D1	D2	% Change	D3	% Change
Autonomous vehicles	How likely students are to ride.	3.81	3.87	1.6%	3.75	−3.1%
	How likely students are to purchase.	2.56	2.38	−7.0%	1.63	−31.5%
Domotics	How likely students are to interact.	3.94	3.81	−3.3%	3.94	3.4%
	How likely students are to purchase.	3.5	2.81	−19.7%	3.38	20.3%
	How vulnerable students believe their data is.	4.19	3.63	−13.4%	3.75	3.3%

Likeliness is measured on a scale of 1 (least likely) to 5 (most likely).

Table 6. Students level of familiarity using smart technology.

Type of technology	Questions	D1	D2	% Change	D3	% Change
Echo Dot	How familiar are students with using the tech.	1.94	2.38	22.7%	3.44	44.5%
Siri	How familiar are students with using the tech.	3.38	3.25	−3.8%	3.81	17.2%
Cameras	How familiar are students with using the tech.	3.75	3.5	−6.7%	3.94	12.6%
TEMI	How familiar are students with using the tech.	1.06	1.00	−5.7%	2.19	119.0%
Drones	How familiar are students with using the tech.	1.69	1.63	−3.6%	2.5	53.4%

Familiarity is measured on a scale of 1 (least familiar) to 5 (most familiar).

students were 3.4% more likely to interact with, 20.3% more likely to purchase, and −3.3% less concerned with security. This suggests that hands on experiences may increase familiarity with emerging technology, while at the same time decreasing fear. Throughout the course, however, students raised concerns about negative impacts on minorities and disadvantaged groups in society on the discussion boards students noted: “They may be cost prohibitive to install or for new jobs, further segregating society” and “Underrepresented people may miss out in their ability to use it, and it will widen the class gap.”

Most notably, after traditional learning, students reported less familiarity with all emerging technologies, except the Echo Dot; familiarity decreased with Siri by −3.8%, cameras by −6.7%, TEMI by −5.7%, and drones by −3.6%. However, after hands on experiences these trends were reversed: students were 17.2% more familiar with Siri, 12.6% with camera, 119% with TEMI, and 53.4% with drones (Table 6). Students appear to gain more familiarity with more complex technologies (drones and TEMI) after hands on experiences. This is illustrated by some of the students’ Twitter posts after using the drones. One student tweeted “Flying the @drone definitely takes some practice” while another tweeted “I did not expect this #drone to be too hard to control.”

Discussion and conclusion

Students entering the workforce will be expected to skillfully implement, knowledgably use, and ethically assess next generation technologies. Whilst we must equip students with the necessary knowledge and skills on emerging technologies, few programs offer consistent pathways to learn both and rarely do so through an experiential approach that engages visual, audio, and kinesthetic learners. Drawing on theories of constructivism (Weegar and Pacis, 2012) and information transfer (Eraut, 2004), this study fills a critical gap in the literature by providing a novel approach for students to learn with next generation technology, the hands on experience, and to assess differences in students' learning outcomes while doing so. The analysis found that traditional learning is associated with increases in knowledge, but hands on experiences likely improve a student's understanding of and familiarity with emerging technologies. In fact, hands on experiences appear to reverse many trends associated with traditional learning. Traditional learning may decrease familiarity or trust, and increase fear, whereas hands on experiences may reverse these trends.

The analysis suggests that hands on experiences and traditional learning may have different effects on student learning outcomes. For example, students in this study reported less familiarity with technology after traditional learning and more familiarity after hands on experiences, particularly for the most complicated technologies, such as drones and TEMI. It is unclear why this is the case. It could be that hands on experiences with the technologies is important for building familiarity with technology, particularly for those that are new, complex, or still relatively uncommon. Similarly, our analysis suggests that hands on experiences may provide students with greater insight into the potential negative consequences of certain technologies. For example, we found that after traditional learning students were less likely to purchase an autonomous vehicle; after hands on experiences this reduced even further. However, it does appear to show increased understanding of the technology in and of itself. The opposite situation occurs with AI-enabled technologies; traditional learning made students less familiar with and less willing to interact with these technologies. However, these trends reversed after hands on experiences, and students became more comfortable with the technology and were more eager to interact with it. Hands on experiences also allowed students to more easily identify the potential challenges associated with implementing AI-enabled technologies, namely, getting other members of society to accept it.

The study also suggests that hands on experiences may help students to more easily identify challenges and potential externalities associated with emerging technology than does traditional learning methods. For example, at the beginning of the course many students reported that merging with traffic could be a major challenge for autonomous vehicles. After traditional learning, these concerns decreased markedly, but they then increased again after hands on experiences as students began to once again become seriously concerned with autonomous vehicles merging with traffic. We identified similar changes in regard to issues such as congestion and environmental impacts. Similarly, students were more likely to recommend autonomous vehicles, or other autonomous transportation technologies, after traditional learning but were less likely to do so after hands on experiences. Though this may show a decrease in trust, it suggests that hands on experiences help students to better predict and understand potential challenges. This is consistent with findings which suggest that hands on experiences increase knowledge and skills (Alavi and Leidner, 2001; Savage et al., 2015). The ability to identify challenges via critical thinking is a key component of successful learning (Facione, 2011). The analysis suggests that traditional classroom learning and hypothetical understanding of technology through thought experiments about current and future technologies may be less successful than hands on experiences in promoting these skills.

This study has some limitations. Though, being a pilot study, some of these are to be expected. Foremost, the sample size was small, at only 15 individuals, all of whom were graduate student from the same university and 13 out of 15 were from the same discipline, all from one university in one country/cultural context. Moreover, the diagnostic itself was long and students may have not been entirely committed to accurately completing it. Students were not randomly selected to participate in the course, nor were they randomly assigned to the hands on experiences module or to specific technologies. Therefore, we can neither conclude that any differences observed between the diagnostics are causal, nor that any trends in student learning observed in this study would generalize to a broader population of students. The conditions were tested sequentially, meaning it was not possible to compare the effect of hands on experiences independently with the baseline. That is to say there were no participants who experienced hands on experiences prior to traditional learning. Finally, the study also suffers from a lack of randomness which limits the ability of formal statistical tests based on either an assumption of random sampling or randomization. We therefore provided descriptive statistics rather than inferential statistics, which show preliminary evidence of a positive impact of hands on experience, but not direct evidence.

This study can serve as a foundation for further research. Testing the hypotheses and methods at different universities and different levels of education, in different cultural contexts, with different demographic backgrounds, and especially with a larger sample size would do well to further research of this topic. A randomized, much larger sample size may also help to provide more direct evidence as to the significance between hands on experience and an improvement in a student's education. Linking the study with different educational theories, for example behaviorism, could further help to refine teaching techniques. Finally, a longer-term study, which examines the impacts of hands on experience in a student's future career choices and successes could further cement the notion that learning with technology leads to long term benefits for students.

Emerging technologies such as autonomous vehicles and artificial intelligence have both classroom and real-world applications. Integrating them into the classroom may provide students with an overall better education, stronger career prospects, and even bridge equitability gaps. The literature suggests that these technologies will fundamentally change the nature of work, and society at large. The students of today are the ones who will ultimately be responsible for the implementation of these technologies tomorrow.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project was funded by Michigan State University's Hub for Innovation in Learning and Technology and the SPDC Director's Built, Natural and Virtual Environment Grant Program.

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References

Al Amir N, Marar A and Saeed M (2018) Eye in the sky: How the rise of drones will transform the oil & gas industry. In: *Abu Dhabi international petroleum exhibition & conference*, Abu Dhabi, 12–15 November, pp.1–7. Abu Dhabi, United Arab Emirates: Society of Petroleum Engineers.

Alavi M and Leidner DE (2001) Research commentary: Technology-mediated learning—A call for greater depth and breadth of research. *Information Systems Research* 12(1): 1–10.

Al-Qahtani AA and Higgins SE (2013) Effects of traditional, blended and e-learning on students' achievement in higher education. *Journal of Computer Assisted Learning* 29(3): 220–34.

Arntz M, Gregory T and Zierahn U (2017) Revisiting the risk of automation. *Economics Letters* 159: 157–60.

Braxton JM, Milem JF and Sullivan AS (2000) The influence of active learning on the college student departure process: Toward a revision of Tinto's theory. *The Journal of Higher Education* 71(5): 569–90.

Bromley K (2012) Using smartphones to supplement classroom reading. *The Reading Teacher* 66(4): 340–4.

Chickering AW and Gamson ZF (eds) (1991) *Applying the Seven Principles for Good Practice in Undergraduate Education*. San Francisco, CA: Jossey-Bass.

Clotet E, Martínez D, Moreno J, et al. (2016) Assistant personal robot (APR): Conception and application of a tele-operated assisted living robot. *Sensors* 16(5): 610–33.

Cui G and Wang S (2008) Adopting cell phones in EFL teaching and learning. *Journal of Educational Technology Development and Exchange* 1(1): 67–80.

Davie N and Hilber T (2018) Opportunities and challenges of using amazon echo in education. In: *International association for development of the information society in 14th international conference mobile learning*, Lisbon, 14–16 April, pp.205–8. Institute of Edcuation Sciences.

Diamond S and Irwin B (2013) Using e-learning for student sustainability literacy: Framework and review. *International Journal of Sustainability in Higher Education* 14(4): 338–48.

Dizon G (2017) Using intelligent personal assistants for second language learning: A case study of Alexa. *TESOL Journal* 8(4): 811–30.

Dommett EJ (2018) Learner ownership of technology-enhanced learning. *Interactive Technology and Smart Education* 15(1): 79–86.

Eraut M (2004) Transfer of knowledge between education and workplace settings. In: Rainbird H, Fuller A and Munro A (eds) *Workplace Learning in Context*. London: Routledge, pp.201–21.

Ertmer PA and Newby TJ (2013) Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly* 26(2): 43–71.

Facione PA (2011) Critical thinking: What it is and why it counts. *Insight Assessment* 2007(1): 1–23.

Fan Y and Yang C (2020) Competition, product proliferation, and welfare: A study of the US smartphone Market. *American Economic Journal: Microeconomics* 12(2): 99–134.

Fredricks JA, Filsecker M and Lawson MA (2016) Student engagement, context, and adjustment: Addressing definitional, measurement, and methodological issues. *Learning and Instruction* 43: 1–4.

Gikas J and Grant MM (2013) Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media. *The Internet and Higher Education* 19: 18–26.

Gusc J and van Veen-Dirks P (2017) Accounting for sustainability: An active learning assignment. *International Journal of Sustainability in Higher Education* 18(3): 329–40.

Hannay M and Fretwell C (2011) The higher education workplace: Meeting the needs of multiple generations. *Research in Higher Education Journal* 10: 1–12.

Herrington J, Parker J and Boase-Jelinek D (2014) Connected authentic learning: Reflection and intentional learning. *Australian Journal of Education* 58(1): 23–35.

Islim OF (2018) Technology-supported collaborative concept maps in classrooms. *Active Learning in Higher Education* 19(2): 131–43.

Kassens-Noor E (2012) Twitter as a teaching practice to enhance active and informal learning in higher education: The case of sustainable tweets. *Active Learning in Higher Education* 13(1): 9–21.

Kassens-Noor E (2016) Flip, move, tweet: A blended course design for different learning environments in urban planning, sustainability, and climate change university courses. *International Journal for Scholarship of Technology Enhanced Learning* 1(1): 83–99.

Kassens-Noor E and Hintze A (2020) Cities of the future? The potential impact of artificial intelligence. Special issue: Artificial Intelligence in the Smart Everything and Everywhere Era. *AI* 1(2): 192–7.

Keengwe J, Onchwari G and Wachira P (2008) Computer technology integration and student learning: Barriers and promise. *Journal of Science Education and Technology* 17(6): 560–5.

Kolb AY and Kolb DA (2005) Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education* 4(2): 193–212.

La Vigne NG, Lowry SS, Markman JA, et al. (2011) *Evaluating the Use of Public Surveillance Cameras for Crime Control and Prevention*. Washington, DC: US Department of Justice, Office of Community Oriented Policing Services. Urban Institute, Justice Policy Center.

Law S and Baer A (2020) Using technology and structured peer reviews to enhance students' writing. *Active Learning in Higher Education* 21(1): 23–38.

Lilly B, Fentiman A and Merrill J (2004) Learning design with artifacts: Single-use cameras as teaching tools. In: *DS 33: Proceedings of E&PDE 2004, the 7th international conference on engineering and product design education*, Delft, The Netherlands, 2–3 September.

Liu Y (2010) Social media tools as a learning resource. *Journal of Educational Technology Development and Exchange* 3(1–8): 101–14.

Lukman R and Krajnc M (2012) Exploring non-traditional learning methods in virtual and real-world environments. *Journal of Educational Technology & Society* 15(1): 237–47.

Ma J and Nickerson JV (2006) Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys* 38(3): 1–23.

Marsh B, Mitchell N and Adamczyk P (2010) Interactive video technology: Enhancing professional learning in initial teacher education. *Computers & Education* 54(3): 742–8.

Mishra P and Koehler M (2006) Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record* 108(6): 1017–54.

Mishra P, Koehler MJ and Henriksen D (2011) The seven trans-disciplinary habits of mind: Extending the TPACK framework towards 21st century learning. *Educational Technology* 51(2): 22–8.

Murchison JM (2010) Ethnography essentials: Designing, conducting, and presenting your research. Research methods for the social sciences Book 25. San Francisco, CA: John Wiley & Sons.

Oliver R and Herrington J (2003) Exploring technology-mediated learning from a pedagogical perspective. *Interactive Learning Environments* 11(2): 111–26.

Palaigeorgiou G, Malandrakis G and Tsolopani C (2017) Learning with drones: Flying windows for classroom virtual field trips. In: *2017 IEEE 17th international conference on advanced learning technologies*, 3–7 July, pp.338–42. IEEE.

Porcaro D (2011) Applying constructivism in instructivist learning cultures. *Multicultural Education & Technology Journal* 5(1): 39–55.

Relles SR and Tierney WG (2013) Understanding the writing habits of tomorrow's students: Technology and college readiness. *The Journal of Higher Education* 84(4): 477–505.

Rollins SP (2017) Teaching in the fast lane: How to create active learning experiences. Alexandria, VA: ASCD.

Sattar F, Tamatea L and Nawaz M (2017) Droning the pedagogy: Future prospect of teaching and learning. *International Journal of Educational and Pedagogical Sciences* 11(6): 1632–7.

Savage E, Tapics T, Evarts J, et al. (2015) Experiential learning for sustainability leadership in higher education. *International Journal of Sustainability in Higher Education* 16(5): 692–705.

Sharmin M, Ahmed S, Ahamed SI, et al. (2006) Healthcare aide: Towards a virtual assistant for doctors using pervasive middleware. In: *Fourth annual IEEE international conference on pervasive computing and communications workshops*, Pisa, 13–17 March, pp.1–6. IEEE.

Shavit T, Lahav E and Rosenboim M (2016) Don't fear risk, learn about it: How familiarity reduces perceived risk. *Applied Economics Letters* 23(15): 1069–72.

Tess PA (2013) The role of social media in higher education classes (real and virtual)–A literature review. *Computers in Human Behavior* 29(5): A60–8.

Veletsianos G (2012) Higher education scholars' participation and practices on Twitter. *Journal of Computer Assisted Learning* 28(4): 336–49.

Weegar MA and Pacis D (2012) A comparison of two theories of learning-behaviorism and constructivism as applied to face-to-face and online learning. In: *Proceedings e-leader conference*, Manila, 2 January.

Wilson BG (2012) Constructivism in practical and historical context. *Trends and Issues in Instructional Design and Technology* 3(1): 45–52.

Yizhong X, Lin Z, Baranchenko Y, et al. (2017) Employability and job search behavior. *Employee Relations* 39(2): 223–39.

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