

Global Journal of Engineering Education

Students' acceptance of CDIO as a crowdsourcing and gamification methodology in IT classrooms: a multiple regression model

Monther Aldwairi†‡ & Ahmed Shuhaiber‡

Jordan University of Science and Technology, Irbid, Jordan†
Zayed University, Abu Dhabi, UAE‡

ABSTRACT: Crowdsourcing, gamification, and the conceive - design - implement - operate (CDIO) framework provide innovative techniques for educating the next generation of engineers. The CDIO method was implemented for an ethical hacking course where students face challenges such as inadequacy of theoretical coverage, and the ramification of the improper use of hacking tools. The study outcomes are suggestions for, and testing of, work designs, as well as the delivery of security courses with CDIO methodology. The courses ran for three semesters and 141 students were surveyed. The data were analysed through structural equation modelling-partial least squares (SEM-PLS) multiple regression analysis. Examined were perceptions and experiences of the CDIO method, and how student attitudes to CDIO could be affected by factors that include enjoyment, interpersonal and technical skills. The relationship between these constructs and how they are influenced was also examined. The conclusions present theoretical and practical implications for researchers and teachers. Specified are research limitations and future work.

Keywords: Information security education, crowdsourcing, gamification, CDIO, SEM-PLS, multiple regression analysis

INTRODUCTION

Information technology (IT) and information security education are facing significant challenges. Some challenges are fuelled by widespread technology and changing habits among the iGeneration, such as continuous Internet connectivity, smart phones and social media [1]. Students are more accustomed to Googling, fact-checking, skimming, messaging, sharing information, multitasking and quick-fixes [2]. Other challenges are linked to the skills building nature of IT courses and the precarious nature of the hacking tools used [3]. In addition, Generation Z students expect instant gratification and a pleasurable experience [4]. College educational systems must keep Generation Z students tuned-in and engaged. Educational systems must adapt to changes imposed by technology and new skills [5].

There have been several attempts to introduce technology into engineering education. However, newer generations are the least satisfied with blended learning as opposed to skills building workshops on the Internet, where they learn those skills required in the workplace [6]. For instance, Noor used smart devices and virtual reality simulations for teaching aerospace engineering courses [7]. Schaefer et al called for lifelong learning, promotion of collaboration and crowdsourcing, as well as the building of professional engineering skills. Despite increased student engagement, the satisfaction was lower than they hoped for [8].

The CDIO (conceive - design - implement - operate) system is an example of an educational method. Project-based learning with the CDIO framework has been included in the teaching of engineering courses. Svensson and Gunnarsson followed the CDIO framework in an electronics and digital systems course [9]. The CDIO method was also implemented in a mechanical engineering senior project course [10]. However, specialised surveys were not performed nor were the findings analysed properly. De León developed a CDIO syllabus for a geology course based on project-based learning (PBL) [11]. A questionnaire was administered and the data were analysed to determine perceptions, expectations and proficiencies. Unfortunately, the majority of the work focused on engineering courses and was not specific to information technology or security [12].

The CDIO framework was also proposed for information technology and computing courses, to bridge the gap between industry needs and IT course outcomes [13]. Some researchers reported increased employability and better software programming skills [14]. More recently, gamification, crowdsourcing and CDIO were introduced into a Web design course [15]. A questionnaire was administered to survey the students' feelings and to collect suggestions. The outcomes of the use of CDIO were based on student game competition or design and no professional study and analysis of the survey was performed. Finally, Almog et al addressed issues with the CDIO implementation for IT courses and suggested new teaching and testing approaches for software development [16].

In earlier work, the authors described the process of mapping CDIO into the ethical hacking life cycle [17], where the concept phase is analogous to capacity building and covering the theory of hacking. By the end of this stage, the students understood network architecture and knew how to perform short hacking exercises [18]. The design stage takes place when the students have formulated a plan and understand how to connect all procedures learnt in stage one. In the implementation stage, the students are given sample vulnerable machines to play with and hack.

Each victim machine is carefully designed to master a specific system hacking vector. The machine sample is modified each semester, for example victim one addresses bypassing authentication through password cracking [19]. The second victim teaches the students to break into the machine through SSH service [20]. The third victim teaches the students about writing malware, setting up malicious domains [21], intrusion detection [22], and launching reverse TCP sessions using the Metasploit framework [23]. The fourth victim teaches the students about SQL injection, Burp suite and decryption.

Finally, the operate stage is when the students participate in a capture the flag (CTF) competition. This gamified project is designed to make assessments fun, taking the stress out of tests and having the student compete in a gamified fashion. This is an iterative process, where the students implement their different hacking plans and adjust to the target at hand. The CTF gamified project is the main assessment, during which Internet collective intelligence and collaboration among the teams are encouraged. Hints and curiosity questions assisted the students to progress through the different hacking stages [24].

RESEARCH METHODOLOGY AND DATA COLLECTION

This research followed a quantitative approach based on observations and measurements. To investigate the learner's perceptions of CDIO, a questionnaire was conducted after the course. The researchers developed a questionnaire instrument containing item blocks of the CDIO dimensions (mastery of concepts and design, and implement and operate in the laboratory), interpersonal skills (teamwork), technical skills (curiosity), perceived enjoyment, attitude towards the course and behavioural intention. A five-point Likert scale was applied (scores ranged from 1 = strongly disagree to 5 = strongly agree, with the neutral score = 3). The survey instrument was refined during a pre-test by employing three faculty members to ensure validity.

This research followed the convenience sampling approach to gather the necessary data from the learners. Convenience sampling is a non-random approach, where results are not projectable to any population other than the students in this sample. Invitations to the on-line self-administered survey were sent to students through a blackboard e-learning system. Six laboratory classes at the CTI College were targeted for employing CDIO at Zayed University, at two campuses (Abu Dhabi and Dubai). In total, 141 senior students agreed to take part in the survey in a three-month period. Then, the data were downloaded from the Google forms portal. By going through the cases, all students' responses were complete and the questions were assigned a value.

In this article, multiple regression analysis is employed to better understand the questionnaire results. The research conceptual model is detailed, loadings and cross loadings are computed, validity and reliability estimates are calculated, and the correlation matrix among constructs is presented.

MULTIPLE REGRESSION ANALYSIS

SmartPLS3.0 was used to perform structural equation modelling-partial least squares (SEM-PLS) multiple regression analysis on the data. Structural equation modelling (SEM) is a casual modelling technique that analyses the structural relationships among latent variables [25]. The PLS regression algorithm usually examines the items and constructs associated with individual constructs (outer loadings), and then examines the structural model by testing the regression paths by running the PLS algorithm and bootstrapping. The threshold point of item loadings is 0.4, but preferably not less than 0.6 [26]. Other items with less than 0.4 item loadings should be eliminated. As a result, all loadings in the present research demonstrated the reliability of items, with all item loadings greater than 0.8, as shown in Table 1.

Convergent validity of constructs was assessed. This refers to the extent to which all associated items are correlated to the same construct. This was examined by the average variance explained (AVE) score, which should exceed the cut-off point of 0.5 [26]. As shown in Table 2, the AVE scores for all constructs exceeded 0.5, which meets demonstrated convergent validity.

The reliability estimates of all constructs were assessed by Cronbach's alpha. This commonly requires a score greater than or equal to 0.70 [25][26]. As presented in Table 2, all Cronbach's alpha scores were found greater than the cut-off point of 0.7, thus demonstrating internal consistency. The discriminant validity was examined to determine how constructs are distinct from one another in predicting the dependent variable [26]. The results in Table 3 indicate that none of the off-diagonal elements exceeded the respective diagonal element, as conditioned in the criterion in reference [25], and thus, discriminant validity was demonstrated.

Table 1: Item loadings and cross-loading.

	Attitude	Behavioural intention	Interpersonal skills	Perceived enjoyment	Technical skills
Att1	0.884				
Att2	0.903				
Att3	0.901				
Att4	0.912				
BI1		0.912			
BI2		0.933			
BI3		0.945			
Iskill1			0.976		
Iskill2			0.978		
Iskill3			0.973		
PE1				0.93	
PE2				0.956	
PE3				0.959	
Tskill1					0.864
Tskill2					0.872
Tskill3					0.903
Tskill4					0.884
Tskill5					0.882

Table 2: Validity and reliability estimates.

	Cronbach's alpha	rho_A	Composite reliability	Average variance extracted (AVE)
Attitude	0.922	0.924	0.945	0.81
Behavioural intention	0.922	0.924	0.95	0.865
Interpersonal skills	0.975	0.975	0.983	0.952
Perceived enjoyment	0.944	0.945	0.964	0.899
Technical skills	0.928	0.93	0.946	0.777

The PLS inner structural model was examined, to investigate the significance of the paths and the predictive power of the model by considering a bootstrapping process. Highlighted in Table 4 are the beta values of each of the latent variables, *t*-statistics, *p*-values and hypotheses results [26]. As a result, all hypotheses were supported at an 0.05 significance level. Shown in Figure 1 is the conceptual model as tested by the SmartPLS3.0 software.

Table 3: Correlation matrix among constructs.

	Attitude	Behavioural intention	Interpersonal skills	Perceived enjoyment	Technical skills
Attitude	0.9				
Behavioural intention	0.882	0.93			
Interpersonal skills	0.556	0.616	0.976		
Perceived enjoyment	0.816	0.809	0.496	0.948	
Technical skills	0.821	0.779	0.597	0.756	0.881

Table 4: Regression paths and hypotheses results.

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	*t* statistics (|O/STDEV|)	*p* values
Attitude -> Behavioural intention	0.588	0.587	0.071	8.233	0
Interpersonal skills -> Behavioural intention	0.167	0.166	0.05	3.317	0.001
Interpersonal skills -> Perceived enjoyment	0.069	0.073	0.079	0.883	0.377
Perceived enjoyment -> Attitude	0.457	0.46	0.084	5.468	0
Perceived enjoyment -> Behavioural intention	0.246	0.248	0.078	3.171	0.002
Technical skills -> Attitude	0.475	0.474	0.082	5.802	0
Technical skills -> Perceived enjoyment	0.714	0.713	0.066	10.797	0

It is noteworthy that the strongest path in the research model is the influence of perceived emotional value on trust in smart meters ($\beta = 0.448$), while the perceived monetary value scored the lowest in affecting intention to use this technology ($\beta = 0.105$), while it was still significant at a 5% confidence level. The variance R^2 indicates the model fitness and the predictive ability of the endogenous variables. The R^2 scores should be greater than or equal to 0.10 [26]. The R^2 value of *intention to use* was found moderate and equal to 65.3%, and 56.1% for the *trust* construct.

Overall, the four dimensions of perceived values are found to have a significant influence on either trust in the smart meter or intention to use it. Perceived epistemic value formulates the awareness about smart meters, which is a vital element to accepting the technology and using it, supporting previous research [27]. Perceived emotional value could also impact users' trust in smart meters, which indicates that users' feelings of pleasure, comfort and security are effective for accepting and using a smart meter. Perceived monetary value in turn could contribute positively and significantly to the behavioural intention, which means that the financial aspect of smart meters in terms of costs and savings can predict the resident's behaviour toward them.

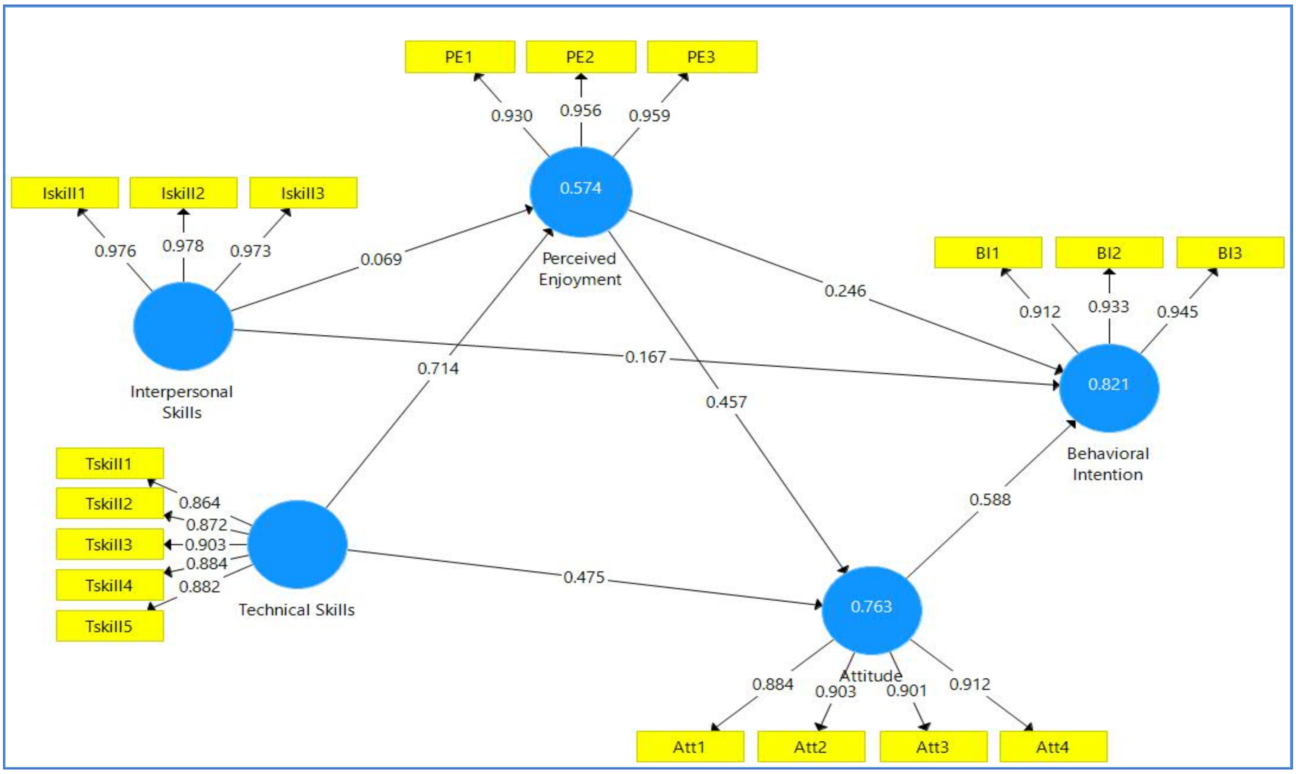

Figure 1: Research conceptual model.

In conclusion, developing students' technical skills during the CDIO laboratory experiments can deeply impact their perceived enjoyment of the laboratory course and their attitudes towards it, which consequently influence their intentions to take more CDIO classes. In other words, the more the technical skills are developed during class, the higher the enjoyment and intention to employ them. On the other hand, the development of interpersonal skills has no significant direct impact on perceived enjoyment, but can significantly and directly influence their usage decision. In this model, the keywords here are perceived enjoyment, which makes the CDIO implementation more acceptable and desirable, by playing the mediating role along with attitude, to achieve higher levels of usage intentions for CDIO-based laboratories.

Additionally, this is what gamification in education is all about; having fun and excitement with the learning content and knowledge delivery method, to achieve the desired learning outcomes. This will not only affect the student-course relationship, but also the student-university relationship by fostering structural and social bonds between the two parties [28].

CONCLUSIONS

Theoretical and Practical Implications

Theoretically, the conceptual model proposed, tested and validated in the current research is novel and contributes to the literature of applying the CDIO framework. The model provides a best practice of how to achieve students' intentions to attend CDIO-based IT and engineering classes for better learning outcomes. In details, developing the technical skills (curiosity and familiarity of IT tools and techniques) and interpersonal skills (teamwork, collaboration and communication) could play an important role in establishing students' enjoyment of, and attitude to, the CDIO framework which, in turn, positively influences students' intentions to accept CDIO-based classes.

For practitioners, teachers and lecturers, they need to consider the benefits of well-established teams and make sure the students are gaining technical skills and are working properly with the learning tools, to enjoy the method to achieve the anticipated learning outcomes.

Research Limitations and Future Work

This research has some limitations. For example, this survey-based study is prone to measurement error similar to other studies that follow survey-based methods. To minimise this, the researchers examined and established the validity and reliability of all constructs. The second limitation is associated with the sampling approach. The results of convenience sampling are usually associated with potential bias and accordingly affect the generalisability of the findings. However, and due to the description and clear phases of the CDIO technique in literature, the present results could extend from IT and engineering classes to other classes, where forming teams to develop members' technical and interpersonal skills is essential. This calls for future research work. In addition, future work might include the examination of other constructs, such as technical support, experiment demonstrations and teacher engagement.

REFERENCES

1. Grubbs, J.B., Exline, J.J., Mccain, J., Campbell, W.K. and Twenge, J.M., Emerging adult reactions to labeling regarding age-group differences in narcissism and entitlement. *PLOS ONE*, 14, e0215637 (2019).
2. Anderson, J.Q. and Rainie, L., Millennials will Benefit and Suffer due to their Hyperconnected Lives. Pew Research Center's Internet and American Life Project, Elon University (2012).
3. Aldwairi, M., Abu-Dalo, A.M. and Jarrah, M., Pattern matching of signature-based IDS using Myers algorithm under MapReduce framework. *EURASIP J. on Infor. Security*, **9** (2017).
4. Rue, P., Make way, Millennials, here comes Gen Z. *About Campus*, 23, **3**, 5-12 (2018).
5. Grudin, J., Technology and academic lives. *Commun. ACM*, 59, **11**, 37-39 (2016).
6. Moore, A.C. and Wells, K.A., Connecting 24/5 to Millennials: providing academic support services from a learning commons. *J. of Academic Librarianship*, 35, **1**, 75-85 (2009).
7. Noor, A., Intelligent adaptive cyber-physical ecosystem for aerospace engineering education, training, and accelerated workforce development. *J. of Aerospace Engng.*, 24, 403-408 (2011).
8. Schaefer, D., Panchal, J.H., Thames, J.L., Haroon, S. and Mistree, F., Educating engineers for the near tomorrow. *Inter. J. of Engng. Educ*., 28, **2**, 381-396 (2012).
9. Svensson, T. and Gunnarsson, S., A design-build-test course in electronics based on the CDIO framework for engineering education. *Inter. J. of Electrical Engng. Educ.*, 49, **4**, 349-364 (2012).
10. Yong, Z.S.M., Namasivayam, S.N., Fouladi, M.H., Mohd Zali, M.A., Quen, L.C. and Hang, M.C., Utilisation of the conceive-design-implement-operate framework in a mechanical engineering capstone project. *Inter. J. of Mechanical Engng. Educ*. (2018).
11. De León, A.T., Project-based learning and use of the CDIO Syllabus for geology course assessment. *Global J. of Engng Educ*., 16, **3**, 116-122 (2014).
12. Wibawa, A.P., Suyono, Lantara, A.D., Purnawansyah, Haviluddin and Dengen, N., Using the CDIO framework to teach research methodology to informatics students. *World Trans. on Engng. and Technol. Educ.*, 16, **4**, 351-355 (2018).
13. Guo, J. and Yan, P., CDIO-based reform of experiment teaching for computer major. *Proc. 2nd Inter. Conf. on Educ. Technol. and Computer,* Shanghai, China, V2-184-V2-186 (2010).
14. Bin, Z. and Shiming, Z., Experiment teaching reform for software testing course based on CDIO. *Proc. 9th Inter. Conf. on Computer Science & Educ*., Vancouver, BC, 488-491 (2014).
15. Song, D., Tavares, A., Pinto, S. and Xu, H., Setting engineering students up for success in the 21st century: integrating gamification and crowdsourcing into a CDIO-based web design course. *Eurasia J. of Maths, Science and Technol. Educ.*, 13, **7**, 3565-3585 (2017).

16. Almog, D., Chasidim, H. and Mark, S., Quality and testing - new teaching approaches for software engineers. *World Trans. on Engng. and Technol. Educ.*, 16, **2**, 140-145 (2018).
17. Aldwairi, M. and Shuhaiber, A., Exploring the integration of CDIO, crowdsourcing and gamification into information security courses. *World Trans. on Engng. and Technol. Educ*, 17, **3**, 237-243 (2019).
18. Widiyaningtyas, T., Dwiyanto, F.A. and Wibawa, A.P., CDIO-based data structure practical coursebook. *World Trans. on Engng. and Technol. Educ.*, 17, **2**, 164-169 (2019).
19. Aldwairi, M., Masri, R., Hassan, H. and El Barachi, M., A novel multi-stage authentication system for mobile applications. *Inter. J. of Computer Science and Infor. Security*, 14, **7** (2016).
20. Alsaadi, H., Aldwairi, M., Al Taei, M., AlBuainain, M. and AlKubaisi, M., Penetration and security of OpenSSH remote secure shell service on Raspberry Pi 2. *Proc. 9th IFIP Inter. Conf. on New Technol., Mobility and Security (NTMS)*, Paris, France, 1-5 (2018).
21. Aldwairi, M. and Alsalman, R., Malurls: malicious URLs classification system. *Proc. Annual Inter. Conf. on Infor. Theory and Appl.*, Singapore (2011).
22. Aldwairi, M., Abu-Dalo, A.M. and Jarrah, M., Pattern matching of signature-based IDS using Myers algorithm under MapReduce framework. *EURASIP J. on Infor. Security*, 2017, **9** (2017).
23. Yaseen, Q., Aldwairi, M., Jararweh, Y., Al-Ayyoub, M. and Gupta, B., Collusion attacks mitigation in Internet of things: a fog-based model. *Multimed Tools Appl*, 77, 18249 (2018).
24. Hrast, Š. and Savec, V.F., ICT-supported inquiry-based learning. *World Trans. on Engng. and Technol. Educ.*, 16, **4**, 398-403 (2018).
25. Hair, J.F., Hult, G.T.M., Ringle, C.M. and Sarstedt, M., *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Thousand Oaks: Sage (2017)
26. Chin, W.W., Marcolin, B.L. and Newsted, P.R., A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Infor. Systems Research*, 14, **2**, 189-217 (2003).
27. Fornell, C. and Larcker, D.F., Structural equation models with unobservable variables and measurement error: algebra and statistics. *J. of Marketing Research*, 18, **3**, 382-388 (1981).
28. Alqirem, R.M., Alnaimi, H.M. and Shuhaiber, A., A best-practice model of university-students relationship development: an empirical study. *Inter. J. of Knowledge Manage*, 14, **4**, 46-67 (2018).

BIOGRAPHIES

Monther Aldwairi has been an Associate Professor at the College of Technological Innovation at Zayed University (ZU) since autumn 2014 and an Associate Professor in Network Engineering and Security at Jordan University of Science and Technology (JUST) since 2012. He received his BSc in electrical engineering from JUST in 1998, and his MSc and PhD in computer engineering from North Carolina State University (NCSU), Raleigh, NC, USA in 2001 and 2006, respectively. Before joining ZU, he was an Assistant Professor of Computer Engineering at JUST since 2007. He served as the Vice-Dean of the Faculty of Computer and Information Technology, from 2010 to 2012, and was the Assistant Dean for Student Affairs in 2008. In addition, he was an Adjunct Professor at New York Institute of Technology (NYiT), from 2009 to 2012. He worked at NCSU as a Post-Doctoral Research Associate in 2007 and as a research assistant, from 2001 to 2007. He worked as a system integration engineer for ARAMEX, from 1998 to 2000. Dr Aldwairi's research interests are in information, networks, Cloud, IoT and Web security, intrusion detection, digital forensics, reconfigurable architectures, parallel architectures and algorithms, artificial intelligence and pattern matching.

Ahmed Shuhaiber has been an Assistant Professor at the College of Technological Innovation at Zayed University since autumn 2018, and an Assistant Professor at Al Ain University since 2016. He earned his PhD degree in information systems from Victoria University of Wellington (VUW), New Zealand, in 2016, and has a computer science and management information systems background for his Bachelor's and Master's degrees. Before earning his PhD, Dr Shuhaiber served as a Lecturer at Al Zaytoonah University of Jordan for many years, and for several years as a teaching and research assistant at Victoria University. Dr Shuhaiber is a qualified Certified International Professional Trainer from the American Certification Institute; a Certified IBM Business Intelligence Analyst; has the ExceLL Intercultural Skills Certificate (Excellence in Cultural Experiential Learning and Leadership) and others; and also serves professionally as a trainer and corporate consultant. Dr Shuhaiber's research interests lie in the fields of smart computing, IoT applications, smart city services, mobile commerce and payments, on-line and virtual learning, and cyber attitudes and behaviours.