Undergraduate Engineering Education and the Game-Based Learning Methods to Promote a Culture of Laboratory Safety

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***Abstract*— This full paper supports areas in the innovative practice category about engineering education and how it has been challenged with integrating labs and experimental practices for student-learning in a traditional setting. The study was created to integrate gamification in the classroom and lab environments for experimental learning with regard to policy that supports safety instructional training within engineering education. Our objective was to identify an approach to promote engineering policies using app development techniques for gamifying lab and classroom practices. This approach also promoted awareness among participants in order to ensure a safety culture designed for learning methods. The gamification techniques were deployed to support engineering courses based on tools involving instructional expectations, policies and procedures. The safety instructional policy was encouraged in student learning by implementing an interactive learning process that identifies specific instructional tools for classroom and lab assessment. This concept of gamification was introduced to engineering practices in order to integrate set policies and course procedures for interactive learning within approach for building a mindset in an educational environment. The gamification concept was used to promote a safety culture and has improved the quality of learning by engaging students in meaningful practices. The concept has also reinforced safety standards for undergraduate engineering students in course and lab instructions. The course and lab instructions were implemented for the purpose of managing and promoting awareness among participants as a systematic approach to foster safe practices in engineering education. Overall, gamification has engaged undergraduate engineering students both inside and outside the educational environment. The undergraduate engineering students would often overlook, ignore or misinterpret the safety practices due to the lack of awareness and safety importance. The gamified approach has identified common malpractices concerning safety instructional policy and guidelines for classroom and lab operation. Gamification of safety instructional policy has created self-awareness to undergraduate engineering students and the influence of safety training procedures was mapped to student-learning outcomes. This technique has had an impact on students, faculty, staff and other support personnel in interacting with classroom and lab equipment through the understanding of operational guidelines and procedures that support engineering education.**

Keywords—Engineering Education; Undergraduate Students; Promoting Safety Culture Concepts; Theory; Game-based Learning

I. INTRODUCTION

Game-based learning has been successfully applied and integrated into the education setting via increasing student participation and the understanding of concepts [1]. Henceforth, there is a lack of consideration using game-based applications with safety policy for undergraduate engineering education [1]. In this paper, we will apply game-based learning to increase safety awareness by using andragogy theory as a tool for implementation in an education environment. The study will provide insight on the theory of andragogy and game-based applications by means of reinforcing safety instructions and policy for engineering education. This research will also introduce the andragogy theory within higher education and the learning experiences between learners and culture [2]. This is critical in the

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development of sustainable life skills by promoting learning experience with the use of game-based learning applications. Whereas, safety policy and procedures are often reviewed as boring and dry among students according to literature [1]. It was also mentioned by authors in their findings that these related challenges in engineernig education are due to safety instructions' presentation within various practices [3]. Therefore, the researchers' goals were not only to promote safety awareness, but also to urge lifelong learning efforts that were suitable and transferred to the workforce environments.

The challenge to create a safety culture in enigneerng education will be critical due to the carry out of performance measures in complex environments and communities [4]. These communities in engingeing education are defined as various stakeholders to support and promote education through collaboration and lifelong learning efforts in technical practices related to workplace environments. In these efforts, the improvement of safety awareness in the education environments are imperative in order to prevent accidents for risk management and quality assurance within educational and industry practices [5]. Many of these practices focus on scientific abilities and behavioral activities widely used to validate instructional policies. According to literature and studies, the implementation processes of safety policy were deemed more effective in industry practices when the promotion of safety awareness become integrated as a culture required for environmental practices [5][6]. The implementation processes in the respective fields also advocate resilience by designing a new safety management paradigm to address culture and mindset [6]. Yet, the nature to explore key research strategies in this case study describes the understanding of engineernig practices among undergraduate students. The study will emphasize how safety instructions and the barriers of implementing policy in higher education could bring awareness within engineernig communities using the andragogy theory for game-based learning tools.

II. Concepts to Promote a Culture in Laboratory Safety

Andragogy is a concept that has evolved into adult learners focusing on lifelong learning techniques [7] [8]. Andragogy was derived from the pedagogical approach and has been adopted as a theoretical underpinning for curricula in higher education [7]. Although the pedagogical approach has been empirically examined in higher education in relation to the assessment of outcomes in education, the theoretical implications are different due to the conceptual framework [8]. As defined in literature, the origin of pedagogy means *leading children* and agogus means *leader of man* [9]. The root of pedagogy was founded in the seventh century with the purpose of introducing organized education at monastic schools (also known as cathedral schools in Europe) [9]. This model was adopted due to the identified benefits it had on the induction of young men into the priesthood based on the educational model implemented [9]. As a result, the teacher-centered model has determined the understanding of what will be learned, how it will be learned, when it will be learned, and if it was learned [9].

In 1833, Alexander Kapp, a German grammar school teacher had introduced the term andragogy to describe the educational change employed by the Greek philosopher Plato [9]. The emergence of andragogy was later described as a theory of adult learning, which expanded into the following concepts: (i) the need to know; (ii) the learner's self-concept; (iii) the role of experience; (iv) readiness to learn; (v) orientation to learning; (vi) and motivation [9]. Thereafter, andragogy was applied to understand the educational process intended for the science of teaching adults and methods in the training process [10]. This approach is now created with the intent to foster lifelong learning methods for engaging students and simulating training environments [11]. These implications have also allowed this study to draw a conclusion based-theory in areas of higher education among research and practices that promote adult learning methods and experiences [11]. This is vital to the promotion of safety educational policies among undergraduate engineering students in the areas of related-workplace environments and training standards associated with the andragogy theory in higher education.

III. Engineering Standards for Laboratory Safety

Instructional activities in higher education should include safety protocols and procedures according to the National Science Teacher Association standards [3]. The National Science Teachers Association has provided standards for students to conduct in the laboratory environments and related workplace environments [3] [12]. These standards were implemented in this study to maintain safe laboratory environments and identify specific safety precautions measures [3]. In each of these instances, the standards were designed to create awareness within the undergraduate engineering education environments in order to bring awareness of inherent risks in the laboratory settings [3]. We begin to analyze these standards and the potential scenarios based on the instructional goals in engineernig practices. These applied practices were used to address the overall user's interaction in the following three (3) categories – (i) protocols and procedures; (ii) situational awareness; and (iii) knowledge and safety policy. These three (3) categories will be discussion throughout the study based on the National Science Teachers Association standards to validate the implemented measures and training protocols for lifelong learning efforts. This is important to the higher education practices for safety awareness, policies and protocols using the andragogy theory.

The requirements used to deploy the identified standards associated with the andragogy theory were designed in the following areas. First, the use of protocols and procedures in safety instructions had provided an understanding to adopt a method of continuous improvement for reasoning and to simulate decision-making practices. The simulation of decision-making practices for continuous improvement is a process to address the core elements needed to understand set strategies concerning the requirements for safety instructional methods [12]. Second, the strategies of safety instructional methods were used to provide an active learning environment for implementation by promoting awareness using game-based learning tools (e.g., activities and conditions) [12]. The third and final approach is the knowledge of safety policies and

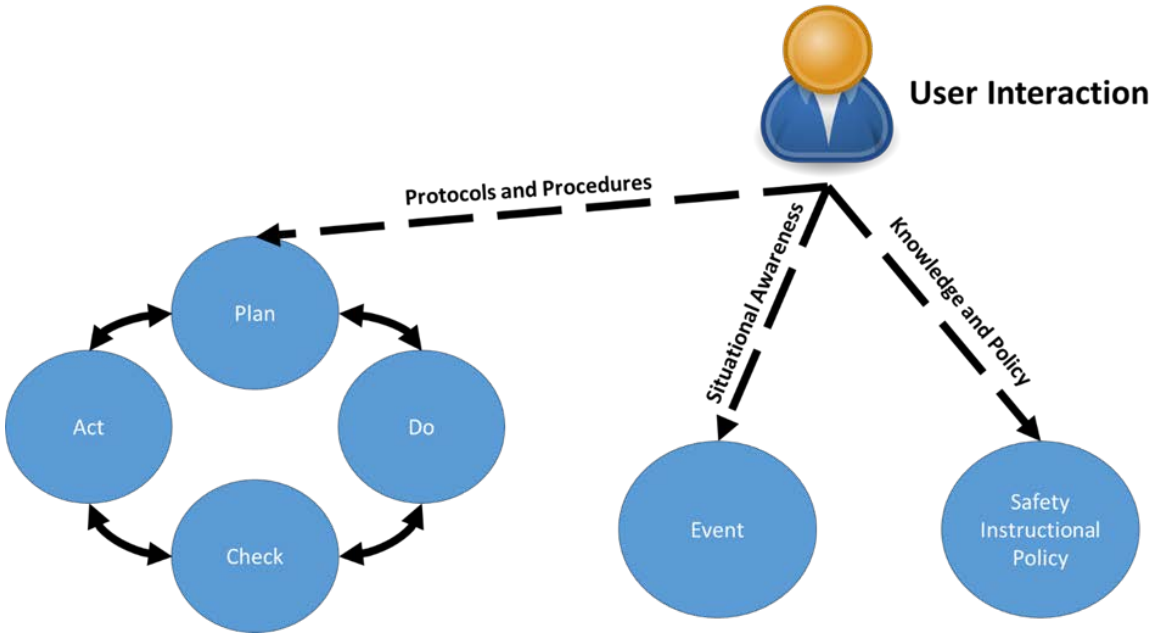

Fig. 1. Educational framework supporting the integration of awareness, plolicies and policies for safety instructions for undergraduate engineering education.

protocols. The knowledge of safety policies and protocols are necessary to lifelong learning efforts defined in higher education standards that are critical to workplace environments and training practices. This study has identified each of the National Science Teachers Association standards and the category associated with the relationship of safety in instructional activities to explore gaps of user interactions and training environments. The figure below is a direct relationship associated with user interaction and the reasoning of safety awareness, policy and protocols based on skills, knowledge, and environmental risk using the National Science Teachers Association standards. This model was implemented to address safety awareness, policies and protocols using andragogy approach for game-based learning within undergraduate engineering education.

IV. Game-Based Learning Environements and the Concepts using Safety Instructions

In the previous section, the andragogy approach was defined as the art and science to facilitate adult learning; in comparison to pedagogy, the art and science of teaching children [13]. This perspective brings about change in ways to facilitate game-based learning environments that support knowledge and skills of educational goals and activities within the andragogy approach [13]. This section will define the educational framework used to facilitate adult learning within the current undergraduate engineering setting and the culture of adopting these six principles: (i) development of concept; (ii) transformation of experience; (iii) skill assessment and readiness; (iv) cognitive orientation to learning; (v) internal motivation; and (vi) formative assessment [13]. The discussion of these six principles are designed to promote a safety culture within undergraduate engineering education using andragogy theory and game-based learning tools.

The game-based learning tool was developed to reinforce engineering concepts and the safety standards in the classroom and lab environments. The tool was implemented for the purpose of managing and promoting awareness among participants as a systematic approach to foster safe practices in engineernig education. The model advocates for the understanding of engineering education practices and was developed using AppyPie, a web-based platform. The platform allowed users to access the technology on mobile app such as Android, iOS, Fire OS, and Windows Phone platforms; in addition to PCs, and other desktop components with internet access. According to the system design, the active game-based environments had feature: (i) memory-based approach, (ii) timed game, (iii) game score results, and (iv) leaderboard performance within a community at various levels (note that this method will create an association of understanding in safety policies through review and repetition of procedures). Moreover, the game-based tool used these features confirmed instructional guidelines and provided insight on responses related to individual behaviors and practices within engineernig education.

The design of the game-based learning tools allowed for the users (undergraduate engineering students) to interact within environments as a community. Whereas, these practices would have often been overlook, ignored or misinterpreted. The reputation of practices encouraged an interactive learning process that was self-directed among individuals. The self-directed learning techniques were influenced by the six principles to advocate safety policies in engineernig practices. This was vital to engineering education and the lifelong learning efforts needed for professional development in the design requirements to understand the integration of andragogy theory and game-based applications for safety instructions in undergraduate engineering education.

TABLE I. PROMOTING A SAFETY CULTURE WITH GAME-BASED LEARNING IN ENGINEERNG EDUCATION

Principles of Promoting a Safety Culture and the Design Approach	**Define Safety Instructions with Game-Based Learning Objectives [13 [15]**	
	Game-Based Learning Objectives	***Promotion of Safety Culture in Engineerng Education***
Development of Self Concept	Create application that is collaborative in environments to ensure learning effectiveness	Establish a climate in identifying critical safety measures for instructional policy
Transformation of Experience	Design a system that involve the learners and interest with related activities	Promote a transformation of experience in education
Skill Assessment and Readiness	Implement a system to formulate results in order to support the overall objective	Encourage the learner to diagnose learning needs and level of competency
Cognitive orientation to learning	Deploy a system to identify problem centered concepts, task and life orientation	Engage the learner to draw from previous experiences and projects
Internal Motivation	Execute a system to allow the learners to be self-directed in order to achieve their goals	Promote a safety culture to use specific resources and the workplace guidelines for a healthy work environment
Formative assessment	Provide a system matrix and the risk association	Enhance historical reasoning and the strategy to provide continuous improvement through systematic feedback

In our study, the mapping of andragogy theory, game-based learning, and safety policies had provided insight on how a safety culture could be integrated in engineerng education. The examination also addressed areas of behavioral and cognitive learning approaches embedded within engineering interdisciplinary and environments. This is critical to the design process and the integration of andragogy theory for game-based learning. In this process, the tools and approach also allowed for the implementation of safety and engineering practices needed in professional development and lifelong learning. These six principles were defined in table below in order to understand ways to promote a safety culture and the guidelines required to using the andragogy theory with game-based learning in engineerng education.

These six principles are key to assure a safe community by promoting awareness within engineerng education. The andragogy approach was applied to address safety instructions and activities used with education experiments. The policies are essential to the environment of active learning and engaging activities related to engineerng practices. As an overview in this section, the andragogy approach provides an understanding of mapping game-based learning applications with safety policies in higher education. Form the aspect of lifelong learning, the game-based learning tool will be used as an intervention to detect risk and reveal preventive measures associated with engineerng practices. Similar to the theoretical approach implemented, the safety polices were developed for the engineerng practices to identify potential guidelines to support education performance and training [16]. This study will present the methods used in the approach to improve overall education and training experiences using safety policies for lifelong learning [16]. These methods will also convey a sense of professional awareness in the engineerng communities that were essential to the goals and mission of the universities and other higher education institutions in order to promote safety instructions.

V. METHODS

The purpose of this study was to examine students' perceptive of game-based learning incorporated to promote safety instructions. The case study focused on the principles described and the aspects of andragogy in order to develop survey questions for students using intervention of reasoning within education practice. The goal was to gather and analyze set methods by uncovering the root causes that affect students in laboratory and classroom environments. The research method was consistent with students' performance and evaluation concerning awareness of safety policies and procedures using the National Science Teachers Association standards and guidelines. The assessment from each of the students' perspective identified advantages and limitations aimed to provide insight for improving lifelong learning efforts in safety awareness [17]. The students received survey questions to create a better understanding in promoting a safety culture based on game-based learning using andragogy theory and concepts provided in an educational environment.

In the case study, the authors had administered to a target population was conducted within the university setting. The population consists of twenty-five (25) undergraduate engineering students using the game-based system to support safety instructions in educational practices. The authors have gather information to ensure that the population was accurately represented. The gathering of information assisted with the feedback from the twenty-five (25) undergraduate engineering students for reliability and validity of the proposed methods presented. The student participants were solely voluntary and the individuals were not coerced into taking the survey. The participants were reminded that each question was voluntary and at anytime they were allowed to withdraw from the research study. The same participants were involved in both the pre-survey and post-survey research process for assessment purposes.

The research process included survey questions adopted from a validated standard tool that addresses three (3) dimensions (e.g., reflective, interpersonal, and technical). This was a critical component in order to address the integration of safety instructions using game-based learning through cross-case analysis with the andragogy theory. The results of the survey from the students' provided information-based responses used to support lifelong learning and methods for delivery. The value of this study helps to identify specific challenges in lifelong learning to improve awareness and safety instructions among students. The andragogy approach incorporated with game-based learning and safety instructions provided flexibility by identifying environmental measures in the research findings. These research findings could potential explore new possibilities of reasoning within reflective, interpersonal, and technical dimensions. In addition, the

finding could also help to identify the gaps that may exist between game-based learning and the use of safety instructions in engineerng interdisciplinary associated with the andragogy theory. These challenges faced in safety practices are vital to the students' decision-making process and workplace environments in this exploratory study.

VI. Results

As part of the result and discussion section, the andragogy theory used techniques within game-based learning to model and construct safety awareness in engineerng education. The university's institutional review board (IRB) approved the survey questions supporting these findings and the participation of human subjects. The results of the study report will be design to address different aspects of lifelong learning efforts by the use of research outcomes. The sample consisted of twenty-five (25) undergraduate engineering students, both male and female population. In the pre and post survey questions, the examination of game-based learning tools for safety awareness was evaluated using the andragogy theory.

The analysis from the contexts of demonstrating analytic and theoretical developments that involved the undergraduate engineering students' supported existing policies and procedures. The findings led to the development of a comprehensive approach and educational findings for safety awareness within engineering practices. The theoretical understanding about the undergraduate engineering students engaged in the study created an understanding about challenges in environmental practices due to missing variables. This also improved the safety culture in laboratory and engineerng practices by indicating the value of lifelong learning and policy awareness. Therefore, the study was only limited to undergraduate engineering students as the targeted group and did not involve the entire student population of the university. In addition to the limitation, the researchers define boundaries in support of a restricted scope could be narrow due to the set objectives and findings (see table and figures below).

TABLE II. Safety Instructions with Game-based Learning Tools

Three Dimensions Mapping	**Crosswalk: Undergraduate Engineering Education Assessment Measures to Promote a Safety Culture**	
	Assessment Measures	***Survey Questions***
Technical Dimension	*Effectiveness*	Do you believe safety instructions were effective using game-based training in order to analysis environment concerns and promote a safety culture in STEM education?
		How effective are safety interactions and evaluation of engineering practices for game-based applications?
		Overall, do you believe that game-based application using safety instructions supports the decision-making process in order to promote a safety culture in engineering education?
Interpersonal Dimension	*Knowledgeable*	Do you agree that integrating instructions for application development will enhance engineering students understanding about safety environments?
		How knowledgeable are you about the concept to promote safety awareness and game-based learning?
		How knowledgeable are about the concept game-based learning used as safety instructional tool?
Reflective Dimension	*Helpful, Satisfied*	Do you believe game-based learning in engineerng education is effective for safety instructions?
		Do you believe that game-based learning is helpful to evaluate safety concepts as a learning experience in engineering practices?
		Overall, are you satisfied with integrating the game-based tools into safety instructional practices for analysis to support engineering education?

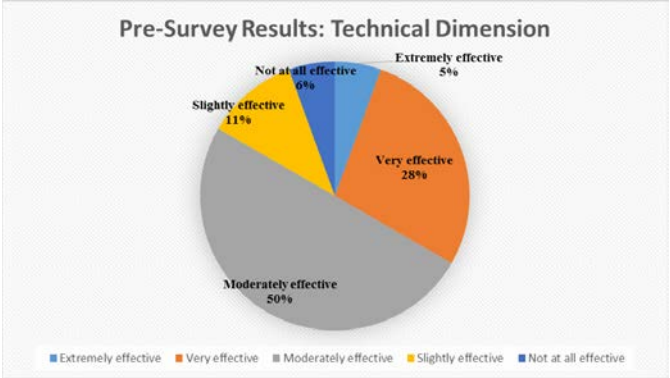

Fig. 2. Pre-survey overall results of the technical dimension and the use of effectiveness measures for undergraduate engineering students

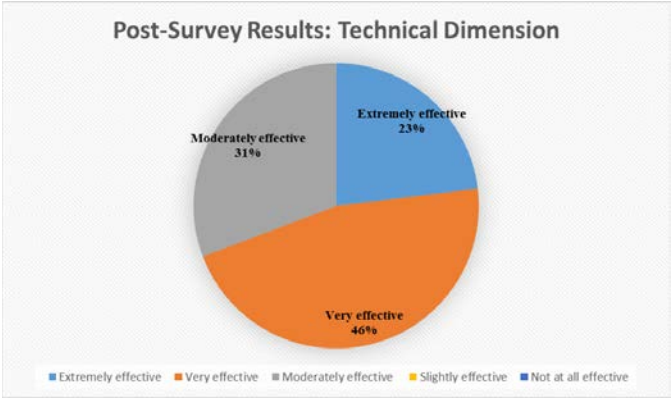

Fig. 3. Post-survey overall results of the technical dimension and the use of effectiveness measures for undergraduate engineering students

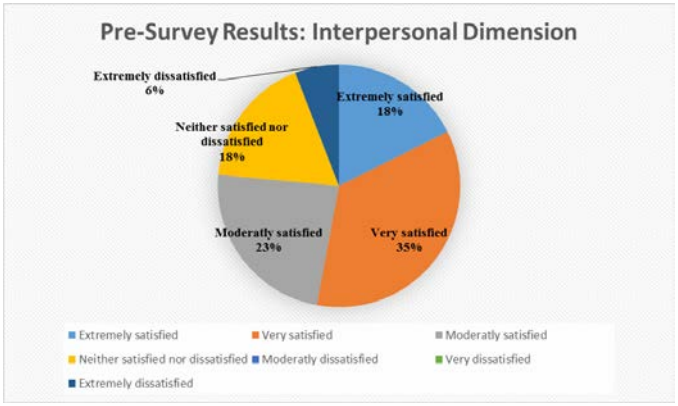

Fig. 4. Pre-survey overall results of the interpersonal dimension and the use of knowledgable measures for undergraduate engineering students

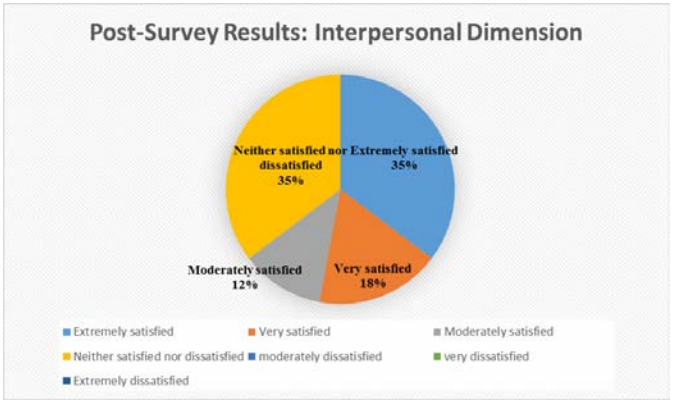

Fig. 5. Post-survey overall results of the interpersonal dimension and the use of knowledgable measures for undergraduate engineering students

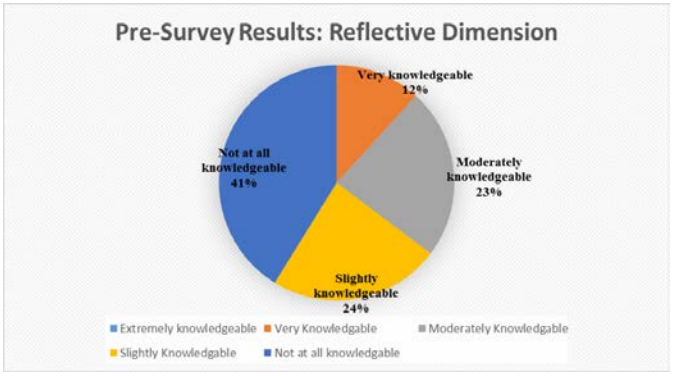

Fig. 6. Pre-survey overall results of the reflective dimension and the use of helpfulness measures for undergraduate engineering students

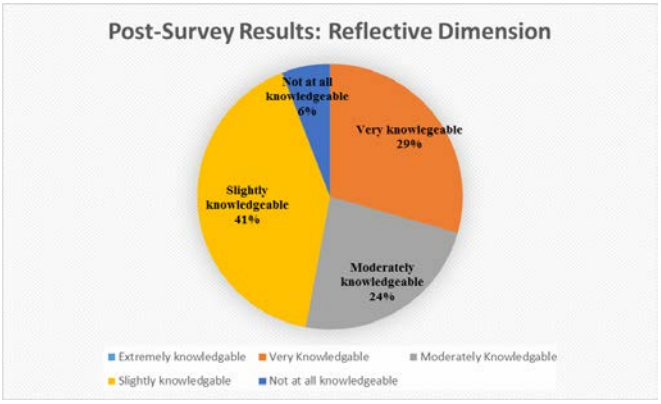

Fig. 7. Post-survey overall results of the reflective dimension and the use of helpfulness measures for undergraduate engineering students

As a result, the integrated game-based learning tool of safety instructional policy found that students valued the opportunity to engage in education research. We had aimed to categorize the results for evaluation of the andragogy theory reinforcing the lifelong learning efforts. The survey data and comments made by students were based on their interaction as users with the game-based system and the experiences within the existing framework and activities. These activities were analyzed to determine the validity of the research study and to highlight implication of perceived student results. The results created a pathway to bridge the gap of safety awareness and student interconnections in related engineering disciplines. The overall results were based on pre-survey and post-survey results with findings provided by undergraduate engineering students. In addition, the discussion had a significant effect on their experiences using specific methods and design approach to promote a safety culture noting this framework has improve the mindset within each dimension as presented in this section.

VII. Conclusion

In conclusion, the findings presented that sometimes all we need is a friendly reminder with regard to lab safety and operations [3] [18]. Andragogy was presented in this study to emphasize development efforts that are consistent with engineering education for shared learning. This is critical to safety management requiring practical implementation of skills learned which are tailored to the instructional policies. In applying the andragogy approach, this study provides a self-directed concept in dealing with safety issues and the use of relevant learning experiences in order to utilize in engineering education [4]. These implications are important in promoting a safety culture for engineering students and their influences that support the individual's decision-making process (e.g., through self-awareness of policies and reasoning). In exploring these methods for engineering purposes, the gamified approach has identified common malpractices concerning safety instructions and the guidelines established by the National Science Teachers Association.

Overall, the evaluation process was designed to inspire undergraduate engineering students and promote a mindset that supports a safety culture. The benefit of this study was also recognized by identifying theoretical challenges in engineering communities and the processes for assessment using data

collection. This study offered specific guidelines for theory building and creating both a mindset and skillset approach using a systematic framework in engineering education. The learning experience of undergraduate students aided an understanding for lifelong learning efforts through the promotion of these safety policies. These implications were vital in the success of safety awareness to foster educational procedures and protocols for undergraduate students specifically to engineering education within laboratory environments and other interdisciplinary concerning workplace practices.

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