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Computer-Based Simulated Learning Activities: Exploring Saudi Students' Attitude and Experience of Using Simulations to Facilitate Unsupervised Learning of Science Concepts

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Abstract: Today, computer-based simulations are widely used in a range of industries and fields for various purposes. They are helpful in testing different scenarios and hypotheses, allowing users to explore the consequences of different decisions and actions. This study aimed to explore the university students' attitudes and experiences of using simulations to facilitate their unsupervised (without teachers' support) learning of science concepts. This study involved 566 university students who used online simulations so support their unsupervised learning of science content in physics, chemistry, math, earth science, and biology. The data collected via a cross-sectional survey were analyzed using parametric statistics. The participants of the study showed a high -level of engagement and satisfaction with the use of simulations for unsupervised science learning, suggesting that computer-based simulations have the potential to serve as a user-centered learning interface capable of engaging university students without the teachers' support. This study did not find a gender-based divide in the students' experiences. Participants' independent learning abilities were found to have a significant positive influence on their satisfaction and engagement. The results of this study have theoretical and practical implications for science learning beyond classroom walls.

Keywords: computer simulations; virtual simulations; science instruction; unsupervised learning; independent learning

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1. Introduction

The enormous capabilities of today's technology have significantly altered how students learn in current times. Educators and students have been making use of computer technology to support their teaching and learning experiences in a variety of ways for several years now. Previous research suggest that computers may play a significant role in laboratory and classroom scientific training [1]. Among the various applications of computer technology for scientific learning, the use of computer-based simulations is on the rise.

Simulation has become a sophisticated tool that can mirror real-world scenarios with considerable precision [2]. They are highly scalable. This means that they can be used to model systems of varying complexity and scale, from small-scale laboratory experiments to large-scale industrial processes. Computer-based simulations can efficiently portray the digital representations of real-life scenarios on computers. While simulation is most often used to analyze complex systems, it may also be used to increase the understanding and skills of the participants through accumulation of experience. The competition-based experiential learning using simulations may be pedagogically constructed as interactive tasks that actors must complete [3].

Students can witness and participate in real-world experiences using computer simulations. Computer simulations are helpful tools for reproducing the results of scientific experiments that cannot be carried out in real life due to factors, such as their complexity, expense, impossibility, or risk. Using computer simulations may contribute to conceptual development. They can also act as a means for scientific inquiry and problem-solving experiences. Furthermore, they can provide experiences for students that reflect real-world scenarios [4].

Self-directed learning refers to the ability of the students to take control of their own learning process, including selecting and using tools and resources that support their learning goals. This is particularly related with computer-based simulations, as they allow students to work at their own pace and explore scientific concepts in a way that is meaningful to them. Computer-based simulations are becoming an increasingly popular tool for imparting science education in many developed countries, offering students opportunities to explore complex scientific concepts and processes in a virtual environment. However, there is insufficient literature on the attitudes and experiences of Saudi Arabian students with these tools, and on how they can be used effectively to support unsupervised learning of science concepts in higher education settings in Saudi Arabia and in other countries which share similar characteristics. Moreover, while the effectiveness of using computer simulations in teaching and learning supervised by teachers are well-supported, their use and effectiveness in an environment that does not involve teachers at all remain sporadic.

Thus, the current study aims to explore the effectiveness of using computer-based simulations for independent (unsupervised) science learning in terms of participants' engagement and satisfaction with such learning activities. Moreover, it also examines the influence of students' prior experience of using simulations and their independent learning skills on their engagement and satisfaction with such learning activities.

The rest of the article is organized as follows. First, a brief review of related literature is presented that provides an overview of computer-based simulations and their use in teaching and learning, particularly in science teaching. Then, the purpose and study questions are presented, followed by a detailed description of the methodology. The article concludes with the presentation of results and a discussion on the findings.

2. Literature Review

2.1. How Do Simulations Work?

Simulations used in education may employ the use of role-play, gaming, and computer models. While using simulations, students' applications of these skills are constrained by rules that are envisioned to permit them to undertake complex tasks whilst barring them from taking actions that are dreadful in the real world [5]. Creating a graphical mock-up of a procedure may be accomplished with the help of a user-friendly simulation software. This graphical simulation needs to incorporate specifics about timeframes, regulations, supplies, and limits to correctly mirror the procedure that takes place in the actual world. It may be used in various contexts. For instance, you might model a grocery store and the behaviors that shoppers will most likely show as they navigate different areas of superstores. Computer simulations may guide choices, such as the requirements for the workforce, factory floor architecture, and distribution network demands, and thus help students in their scientific experiments. Another example would be a manufacturing environment, in which distinct assembly line components may be simulated to evaluate how their processes interact with those of other components. It may also provide a snapshot of how the overall system will function, which can be helpful when thinking of novel ways to increase performance [6].

2.2. Computer Simulations in the Process of Education and Learning

The tremendous growth in computer technology has affected how computers are used in the classroom. As a result, there is a movement away from printed educational materials and towards digital ones [7]. Today, learners can locate facts, grasp scientific ideas and principles, and develop intellectual abilities via learning activities developed by a scientist if they participate in computer-based simulations. Numerous academic fields have been using simulations, including medicine, business, political science, aviation, and biotechnology [5,8].

Computer-based simulation is a great way to achieve guided practice in a range of scenarios that learners would not easily experience during their time in schools, colleges, or universities. According to the research findings from a recent study, there is a strong connection between using computer simulations and the students' acquisition in teaching and learning processes [9]. Enhancing the availability of knowledge, ideas, and challenging topics that have been conveyed and communicated is one way that computer simulations can potentially transform learning. It is accomplished by providing educators with additional opportunities and students with increased opportunities for collaboration with peers and experts.

On the other hand, the research found that even though computer simulations are superior to more conventional methods of instruction in teaching science, it has been decided that they should only be employed in classrooms if the instructors deem it necessary. Actual research labs, not simulations, can help students in learning scientific concepts and facilitate their teaching in a comprehensive and simplified manner [10]. This approach should make it simpler for students to comprehend the phenomenon entirely. In a computer simulation environment, students can methodically investigate hypothetical scenarios, alter the time scale on which events and actions occur, and work through challenges in a realistic setting while remaining stress-free. Researchers also highlighted that solely incorporating simulations courses is unlikely to impact pupils, particularly those with a low reasoning capacity and who need help to successfully cope with learning new scientific ideas and concepts that demand significant cognitive abilities [11].

2.3. The Use of Computer Simulation in Science Subjects

According to Hırça and Bayrak, students may analyze hypothetical scenarios systematically, serving as a condensed portrayal of an engaging system or procedure [12]. They additionally possess the ability to adjust the time scale of events and activities, apply what they have learned, and have the benefit of being able to solve issues in a realistic setting while remaining stress-free [13]. On the contrary, Supriyatman and Sukarno asserted that compared to simulations, the experimental procedure which incorporates actual items, tools, and measuring equipment, is more successful in learners' cognitive accomplishment and developing scientific abilities [14]. Unfortunately, not all scientific topics can be explained by conducting experiments in a lecture hall [12]. Some specific scientific topics or phenomena are hard to witness directly. For instance, Siswanto et al., explained that parabolic motion, an integration of uniformly augmented and accelerated motion, can be demonstrated by simulation in the most detailed form [15].

Experts argue that the PhET simulation allows for visualizing the many kinds of energy and the changes that occur during one's daily life [16]. Thus, it is of utmost importance to use instructional activities that can adequately show the fundamental principles of science and ensure that students properly comprehend this material [15]. Among the most popular and easy-to-use software programs in science education is the PhET. This program is a simulation that the Colorado State University created. PhET simulations are intended to explain the fundamentals of physics, biology, chemistry, and other science subjects to facilitate learning in the classroom or on an individual level [17].

Another study stated that simulations are techniques that may efficiently enhance science learning [9]. While working with simulations, adhering to the established pedagogical practices that have been shown to facilitate effective learning is essential. Learners should be encouraged to take responsibility for their education and should be expected to actively participate in acquiring new information. The subject of science should be situated within the framework of the actual world [18].

Science educators are increasingly using interactive science simulations, and study shows that this new technology can enhance student learning [19]. Researchers argue that the use of simulation-oriented activities in teaching and learning can enhance learners' theoretical as well as practical understanding of various scientific knowledge and skills [20]. The need to thoroughly comprehend the intricate processes involved in science exploration is the primary driver behind the use of simulation—for example, genetics, molecular size, atoms, or molecules. According to Hmelo, Holton, and Kolodner, the structures of complex systems are the aspects that can be learned with the least effort. In molecular genetics, it is essential to understand the structures of molecules, such as DNA and RNA to understand their features properly [21]. In this situation, simulations may help organize the little bits of knowledge into more significant pieces of information, which can reduce the amount of memory necessary by strengthening the logical linkages between concepts [22]. Learners can examine and engage with models of processes and phenomena via simulation [23]. Students' grasp of scientific ideas on a molecular level may be improved by using simulations that allow for the visualization of processes. It helps students in linking mental pictures to the notions [24].

Researchers argue that a mental model is an appreciation and interpretation of an individual's view of what exists [7]. This understanding and assessment is produced and reformed by the individual's behavior, ideas, attitudes, socio-cultural background, and previous judgments. How one interprets new ideas and occurrences is influenced by the mental models. Learners understand that physical representations may assist them in developing their mental models and understanding new ideas, and many areas of science require students to establish their mental models [20].

2.4. Simulations and Human-Computer Interaction (HCI)

Simulation and Human-Computer Interaction (HCI) are two closely related fields that intersect in several ways. Simulation is the process of creating a computer model or representation of a system or process to gain insights into its behavior or to evaluate its performance under different conditions [25]. Simulations can be used to test various scenarios, optimize designs, and make predictions about how a system might behave in the real world. Human-Computer Interaction (HCI), on the other hand, is the study of how people interact with computers and other digital technologies. HCI researchers aim to understand the cognitive and social processes involved in human-computer interaction and to design user interfaces that are intuitive, efficient, and effective.

The connection between simulation and HCI lies in the fact that simulations can be used as a tool for studying and evaluating user interfaces [26]. For example, simulations can be used to test different interface designs and evaluate their effectiveness in supporting user tasks. They can also be used to study the cognitive processes involved in human-computer interaction, such as attention, memory, and decision-making. In addition to studying user interfaces, simulations can also be used to create virtual environments that support immersive and interactive teaching and learning experiences. For example, virtual reality and augmented reality technologies, use simulation to create digital environments that users can interact with in a natural and intuitive way. Particularly, if the computer simulations are to be used for learning by students independently (without the support of a teacher), it is required that the interface design of these systems meet the principles HCI, such as user-centeredness, feedback, learnability, and error prevention. This is to ensure that the learners have an interactive learning system that is easy to use, efficient, and satisfying to interact with comfortably on their own [27].

2.5. Attitudes and Experiences of Learners' Use of Simulations

Despite the growing evidence regarding the use of simulations as an effective teaching tool, the education system has not used simulation technology infrequently. The findings of this research provides credence to the crucial function that simulation plays in disseminating knowledge in the interests of education. Students' attitudes about science might have been altered due to their involvement in the live simulation over time [28].

Simulations can significantly increase people's knowledge of STEM-related job opportunities. The realistic simulation educational environment can change students' self-perceptions and goal orientations, coinciding with the national effort to boost students' awareness of STEM-related occupations. This kind of high-tech computer-assisted cooperative simulation of a real-life scenario activates practical learning as well as boosts professional identity, consciousness, motivation, and creation [29].

The research discovered that there is a gender gap when it comes to views on science as well as the desire to pursue professions in the scientific field [30]. Males tend to be more open and responsive to scientific attitudes, such as finding new things, and are more interested in pursuing science-related occupations. According to research, the gender of a student is the single most crucial factor in determining their attitude toward science [30].

The assessment of the relevant literature reveals that simulation can play significant roles in the classroom setting of science and the teaching of science [14]. Learners are provided with the chance to watch and participate in a real-world experience via the use of simulation. In scientific education, students may acquire knowledge of complex subjects via computer simulations, which facilitates experiential learning. According to the findings of this research, simulations benefit students' conceptual grasp of scientific concepts.

3. Research Purpose and Questions

This current study is primarily aimed to explore and examine Saudi students' experiences of using computer-based simulations to support their unsupervised (without teacher's support) learning of science concepts. Moreover, the study seeks to examine the possible influence of students' independent learning abilities and prior experience of using simulations on the levels of their satisfaction and engagement when they experience simulations to support their unsupervised learning of science concepts. This study is guided by the following research questions:

1. How engaged and satisfied Saudi students feel when they experience computer-based simulations to support their unsupervised learning of science concepts?
2. Do the male and female students have significant differences in their levels of engagement and satisfaction when they experience simulations to support unsupervised learning of science concepts?
3. Does students' prior experience of computer simulations predict the engagement and satisfaction levels when they experience simulations to support unsupervised learning of science concepts?
4. Do students' independent learning abilities significantly predict the engagement and satisfaction levels when they experience computer simulations to support unsupervised learning of science concepts?

4. Materials and Methods

In order to explore the university students' experiences of using computer-based simulations for learning science concepts, the present study followed a cross-sectional survey design. Such a survey is an efficient way to provide a snapshot of the population's characteristics, such as demographics, behaviors, attitudes, or health outcomes [31]. This study followed a quantitative approach in collecting and analyzing data.

4.1. Study Participants

The investigation took place in a public Saudi university where the researcher is affiliated. The population of the study was university students enrolled in various programs at the undergraduate level. A total of 566 students participated in the study. The participants included 52 percent male (n = 296) and 48 percent female (n = 270) students. They belonged to a mix of academic disciplines including business management, engineering, technology, social sciences, medicine, and natural sciences. The participants' age ranged between 18 and 24 years. With a mean age of 21.27 (SD = 1.889) years, most of the participants were 22 (n = 101, 17.8%) and 23 years old (n = 99, 17.5%).

4.2. Research Measures

The present study employed an anonymous survey questionnaire as the primary research measure (see Appendix A). The questionnaire consisted of close-ended items adopted from previous studies. In addition to some demographic items, the questionnaire included Likert scales to record respondents' satisfaction with simulated learning (3 items), their engagement with simulated learning (10 items), and their independent learning abilities (6 items). Table 1 shows the main categories of survey items and the source of previous research from they were adapted. Before using the questionnaire for actual data collection, it was first assessed by three experts/senior researchers in the field and was pre-tested on a group of 10 participants to ensure that the items included in the survey are interpreted correctly by the sample target.

Table 1. Sections in survey questionnaire.

Survey Section	Adapted from
Demographics	Self-developed
Satisfaction with Simulations	Jefferies and Rizzolo (2006) [32]
Engagement with Simulations	Lindgren et al. (2016) [33]
Independent Learning Abilities	Macaskill and Taylor (2010) [34]

4.3. Simulation-Based Learning Activities

Prior to completing the survey questionnaire at the end of the fall 2022 semester, the study participants experienced at least one of the simulation-based learning activities of their choice in their preferred area of science learning, such as physics, chemistry, math, earth science, and biology, without the support of any teacher. The pool of open PhET resources (https://phet.colorado.edu/ (accessed on 10 October 2022)) was used for this purpose. These open simulation resources are part of the PhET Global initiative from the University of Colorado which aims to improve the quality of global math and science education around the world. About 250 million sessions take place per year which reflects the huge impact of this initiative. More than 24,000 teachers across the globe benefited through PhET programs in 2021. Science teachers have been using PhET simulations for their in-class activities as well as for virtual labs. These simulations provide a venue where learners involve in inquiry and scientific knowledge acquisition [19].

The PhET website allowed students to practice simulations without any registration process. The participants could use these simulations at anytime and anywhere as per their convenience. Further, they were not assigned any specific subject area to practice simulations and were open to choose simulations from any science area including physics, chemistry, math, earth science, and biology. The time spent on simulations by each student varied depending on various factors, such as the subject area, and number of interactions between the user and simulations. Figures 1 and 2 provide glimpses of simulation-oriented virtual activity for learning projectile motion and molecule polarity, respectively, used in this study. These simulations allowed the participants to experience the dynamic behavior of science concepts based on their interaction with various characteristics/values of the respective scientific phenomenon.

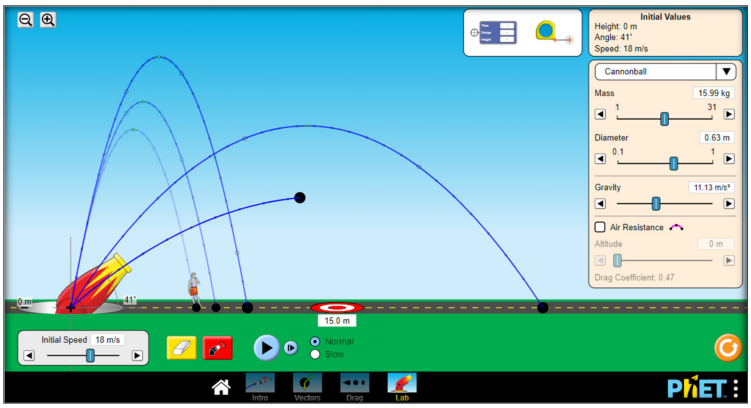

Figure 1. Simulation-based activity for learning projectile motion.

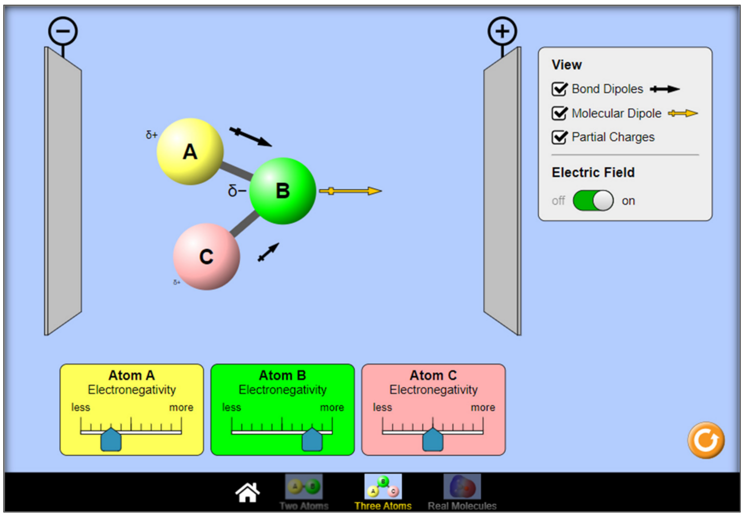

Figure 2. Simulation-based activity for learning molecule polarity.

4.4. Data Analyses

Bearing in mind the kind of research and the fix-set type of items included in the survey form, all data were examined through a quantitative approach in SPSS, version 26. We used descriptive statistics consisting of frequency, mean, and standard deviation and inferential tests, such as student's *t*-test and simple linear regression. The significance level for the inferential tests was fixed at $p < 0.05$.

5. Results

This study primarily investigated Saudi university students' attitudes and experiences of using computer-based simulations for learning science concepts independently. The main results of the current investigation are presented in respect to the four research questions.

5.1. Engagement and Satisfaction with Simulation-Oriented Learning Activities

The first research question attempted to examine the levels of university students' engagement and satisfaction with the use of online simulation-based activities for learning science concepts without the support of a teacher. More specifically, we were interested to see (1) how well the study participants were engaged in the learning process when they interacted with the simulation-based learning activity without the teachers' support, and (2) what was the level of their perceived satisfaction with these activities. To address these questions, students' perceptions were recorded using two different measures adapted from Jefferies and Rizzolo (2006) and Lindgren et al. (2016), respectively. Both scales were formatted on a 5-point Likert scale ("Strongly Disagree" = 1, "Disagree" = 2, "Neutral" = 3, "Agree" = 4, "Strongly Agree" = 5). The data were analyzed by creating separate factor scores for the two factors: (1) Engagement with simulations and (2) Satisfaction with simulations. Negatively worded items were reverse-coded before taking the averages of the sub-scales so that a higher score value depicts a higher state of engagement and satisfaction with the learning activity as perceived by the study participants.

The factor scores reflected an overall positive perception of university students towards of using computer-based simulation to support their independent (unsupervised) learning of science concepts. Results indicated that participants' perceptions were just a little higher for the satisfaction factor (M = 3.671, SD = 0.966) than for the engagement factor (M = 3.656, SD = 0.793). These results suggest that the participants' engagement and satisfaction with the simulation-based learning of science concepts were on the positive side.

5.2. Gender-Based Divide in Students' Learning Experiences

In the second research question, we were interested to see whether the levels of participants' engagement and satisfaction with simulations activities were equal for male and female university students or if there were any significant gender-based differences in the two factor scores. Gender-based differences in the participants' perceptions were tested using an independent sample *t*-test (see Table 2).

Table 2. Independent *t*-test results to test gender-based differences.

Factors	Gender	N	Mean	Standard Deviations	*t*	*Sig*
Engagement	Male	296	3.70	0.79	1.282	0.200
	Female	270	3.61	0.78		
Satisfaction	Male	296	3.72	0.96	1.127	0.260
	Female	270	3.62	0.96		

The findings from the independent sample *t*-test revealed no significant differences between males and females in their perceived engagement levels, $t(564) = 1.282$, $p > 0.05$; as well as their satisfaction with the simulation-based learning activities for science learning without the teachers' support, $t(564) = 1.127$, $p > 0.05$. In simpler words, these results suggested that male and female study participants have almost similar levels of engagement and satisfaction with unsupervised simulation-based science learning.

5.3. The Effect of Prior-Experience with Computer Simulations

The third research question of this present study sought to confirm whether students' experience of using computer simulations prior to their participation in the current study predict their engagement and satisfaction state. Most of the participants (62%) had little to extensive prior experience of using simulations. However, many (38%) reported that they never used computer-based simulations prior to this study. Figure 3 depicts study participants' prior experience of using simulations.

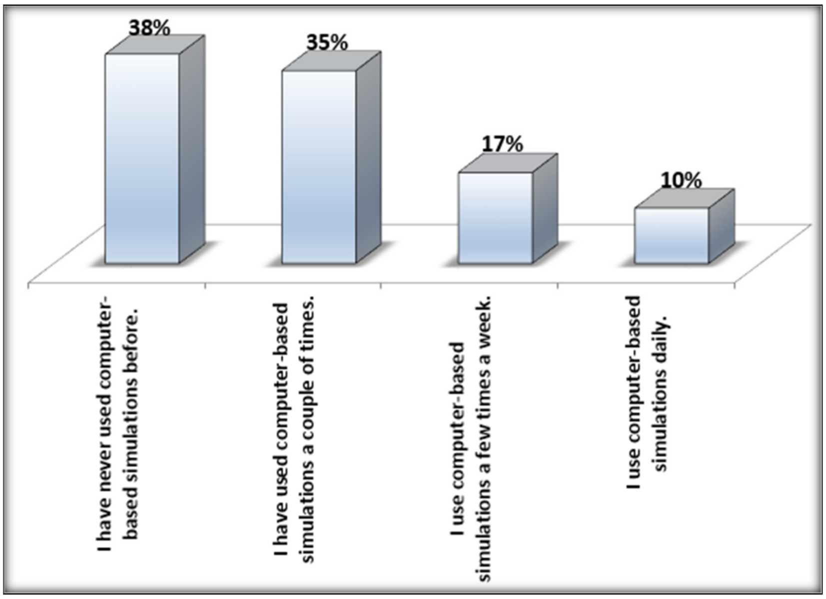

Figure 3. Study participants' prior experience of using simulations.

We performed simple linear regressions for each of the two factors (engagement and satisfaction) with prior experience as a predictor variable (see Table 3). The results of regression analysis indicated that participants' prior experience of using simulation has a statistically significant impact on both the engagement and satisfaction in a simulation-oriented science activity; $p < 0.05$. However, the weight of the predictor was found to be very nominal.

Model 1 (Engagement) has the least R^2 value (R^2 =0.008, $p < 0.05$), explaining a very minute but significant amount of variance in the participants' engagement with simulations-based science learning. The standardized regression weight for prior experience (β = 0.092, $p < 0.05$) indicated that it explained only less than 1% of the total variance in engagement (see Table 3). Similarly, Model 2 (Satisfaction) has the least R^2 value (R^2 = 0.010, $p < 0.05$), explaining a very minute but significant amount of variance in the participants' satisfaction with simulations-based science learning. The standardized regression weight for prior experience (β = 0.098, $p < 0.05$) indicated that it explained only less than 1% of the total variance in satisfaction (see Table 3). In other words, the regression models suggested that the prior experience significantly influences both engagement and satisfaction positively. However, its weightage for the prediction of two dependent variables is very nominal.

Table 3. Regression Results: Prior Experience Predicting Engagement and Satisfaction.

Regression Model	R^2	Prior Experience (β)
Model 1 (Engagement)	0.008 *	0.092 *
Model 1 (Satisfaction)	0.010 *	0.098 *

* $p < 0.05$.

5.4. The Effect of Independent Learning Abilities

Our fourth question was focused to examine the influence of students' independent learning abilities on their engagement and satisfaction levels while experiencing computer simulations to support unsupervised learning of science concepts. We conducted simple linear regressions for each of the two factors (Engagement and Satisfaction) with Independent Learning Abilities as a predictor variable (see Table 4). The results of regression analysis indicated that participants' independent learning abilities have a statistically significant impact on both the engagement and satisfaction with a simulation-oriented science activity; $p < 0.001$.

Table 4. Regression results: independent learning predicting engagement and satisfaction.

Regression Model	R^2	Independent Learning (β)
Model 1 (Engagement)	0.454 **	0.674 **
Model 1 (Satisfaction)	0.310 **	0.557 **

** $p < 0.001$.

Model 1 (Engagement) has a moderate R^2 value (R^2 = 0.454, $p < 0.05$), explaining a moderate significant amount of variance in the participants' engagement with simulations-based science learning. The standardized regression weight for independent learning abilities (β = 0.674, $p < 0.001$) indicated that it explained a minute part of the total variance in engagement (see Table 4). Similarly, Model 2 (Satisfaction) has the least R^2 value (R^2 = 0.310, $p < 0.001$), explaining a moderate significant amount of variance in the participants' satisfaction with simulations-based science learning. The standardized regression weight for independent learning abilities (β = 0.557, $p < 0.001$) indicated that it explained a significant of the total variance in satisfaction (see Table 4). In other words, the regression models suggested that independent learning abilities have a significant positive influence both the engagement and satisfaction.

6. Discussion

Science teachers around the globe are leveraging the flexible characteristics of computer simulation to undertake a range of learning tasks, specifically to engage students in acquiring scientific phenomena [19]. This study sought to explore and examine the Saudi students' experiences of using computer-based simulations to support their unsupervised (without a teacher's support) learning of science subjects, such as physics, chemistry, biology, mathematics, and earth science. Our investigation empirically found that university students felt very engaged and satisfied with the use of simulation-based activities to facilitate scientific knowledge acquisition independently. Here, participants' high level of engagement and satisfaction suggests that the design of the simulations, particularly that of the PhET resources, is intuitive, efficient, and effective, ensuring that users can easily and comfortably interact with these resources. This is in line with the basic design principles of human-computer interaction (HCI) that aims to create user-centered interfaces that meet the needs of users and allow them to accomplish their tasks with minimal effort and maximum satisfaction [26].

Our results regarding participants' engagement and satisfaction with simulations not only aligns with the findings from previous research that support simulations as an effective teaching tool [5,19,20,35] but also provides empirical evidence for a new aspect of their pedagogical use, i.e., their potential for independent (without the teachers' support) learning of science concepts. Teachers' presence and support is a mandatory requirement for science practical when conducted in actual science labs that require the use of expensive and sensitive material. Since there is no scope of physical or monetary loss when the science practical is conducted virtually, teachers' non-participation or absence can be afforded as students learn about scientific phenomena from trial and error by interacting with different characteristics and input values within a simulation-based activity. This sort of unsupervised learning will be particularly beneficial for the students who learn better in independent settings and enjoy flexibility, autonomy, ownership, and lifelong learning. At the same time, challenges, such as isolation, limited feedback, and being overwhelmed may also be faced that needs to be tackled wisely while asking students to engage in independent or self-directed learning.

Our study did not find evidence of statistically significant gender-based differences regarding university students' engagement and satisfaction with simulation-oriented science activities. This implies that both male and female students equally benefitted from the computer-based simulation. The absence of gender-based differences in the use of computer simulations is consistent with the findings of Soomro and Jabeen, which suggest that gender-based differences in digital competence and practices are no longer widening but are rather disappearing across the globe [36]. Moreover, since the study participants were able to interact with the system comfortably, and perceive and interpret information presented efficiently regardless of their gender, we consider that the system was inclusive which is an important characteristic of human-computer interaction (HCI) [37].

Though our results indicated that the students' prior experience of using simulations affect their engagement as well as satisfaction with using these technologies for independent science learning, the effect of this variable was found to be very minute. However, the major factor that affects the engagement and satisfaction significantly was students' independent learning abilities. This implies that the students' skills, such as self-directed learning, play a vital and positive role in benefitting from the pedagogical aspects of computer-based simulations without the need for a teacher.

Here, we also feel the need to acknowledge the limitations of the current investigation. Recognizing limitations is a crucial stage in the research process because it enable researchers to be open and honest about the possible weaknesses in their study as well as enable readers to assess the study's findings and conclusions in light of those limitations. Firstly, the current study is based on self-report data, which may be subject to biases and inaccuracies. The study only examines the perceptions of students in tertiary education in Saudi Arabia, and the findings may not be applicable to other contexts or populations. We would strongly recommend exploring the potential of simulations for unsupervised learning with other student populations, such as school students, who may not have sufficient independent learning abilities and where the age range of the participants is not smaller than university students.

Further, this study is a cross-sectional study, which means that it can only identify associations between variables at a single point in time, but cannot establish causality or temporal relationships. Conducting a longitudinal study might be helpful in examining how students' engagement and satisfaction regarding the use of simulation for learning evolve over time and how this change is linked to the actual use of such tools. Additionally, conducting a qualitative study would be helpful to gain a deeper insight into the factors that influence students' satisfaction and engagement with simulations and similar technologies.

7. Conclusions

This study examined university students' attitudes and experiences of using simulations-based activities to facilitate their unsupervised knowledge acquisition of science content of subjects including physics, chemistry, math, biology, and earth science. We found that students reported a high-level engagement and satisfaction with such activities for science learning even when teachers are not available to support them. This study provides significant evidence for the potential of computer-based simulation to be used as a user-centered learning environment for science content where participants can interact with the system independently. The results of this study do not report any gender-based divide in students' engagement and satisfaction with simulations. Moreover, independent learning abilities were found to be a significant positive influencer of learners' satisfaction and engagement in simulation-oriented learning of science concepts.

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Institutional Review Board Statement: The study was approved by the Standing Committee for Scientific Research Ethics KSU-HE-21-861.

Informed Consent Statement: An informed consent was obtained from all the participants.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A Survey Questionnaire

Q1. What is your gender?

- ◻ Male
- ◻ Female

Q2. How old are you?
______ years
Q3. What is your major (program of study)?

____

Q4. Please indicate your prior experience (before participating in the current study) of using computer-based simulations for learning **any** subject?

- ◻ I have never used computer-based simulations before.
- ◻ I have used computer-based simulations a couple of times.
- ◻ I use computer-based simulations few times a week.
- ◻ I use computer-based simulations daily.

Q5. In which of the following science area did you experience simulations for this study? (Please check only one).

- ◻ Physics
- ◻ Chemistry
- ◻ Math
- ◻ Earth Science
- ◻ Biology

Q6. Considering your recent experience with the computer-based simulations in the science subjects (Physics/Chemistry/Math/Earth Science/Biology), please indicate your level of agreement (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly agree) with the following statements:

Satisfaction	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The teaching methods used in this simulation were helpful and effective.	□	□	□	□	□
The simulation provided me with a variety of learning materials and activities to promote my learning in the sci-ence subjects.	□	□	□	□	□
The teaching materials used in this simulation were motivating and helped me to learn.	□	□	□	□	□

Q7. Considering your recent experience with the computer-based simulations in the science subjects (Physics/Chemistry/Math/Earth Science/Biology), please indicate your level of agreement (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly agree) with the following statements:

Engagement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
My seeing and hearing senses were used fully in the simulations.	□	□	□	□	□
I lost track of events happening in the real world while I used this simulation.	□	□	□	□	□
I felt like I was really there.	□	□	□	□	□
I felt enthusiastic while using the simulation-based learning activity.	□	□	□	□	□
It was easy to concentrate on the simulation.	□	□	□	□	□
I felt the simulation held my attention.	□	□	□	□	□
The simulation had features that helped me overcome challenges.	□	□	□	□	□
I remained focused during the simulation-based learning.	□	□	□	□	□
I felt like I could control the things that happened in the simulation.	□	□	□	□	□
I understood my overall goals in the simulation.	□	□	□	□	□

Q8. If made optional, how much you are willing to use computer-based simulations for science learning in future:

□ Definitely Not
□ Probably Not
□ Probably
□ Very Probably
□ Definitely

Q9. The following questions relate to your personal learning experiences in the context of your studies in general. Please rate the following statements as honestly and sincerely as possible.

Independence of Learning	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I enjoy finding information about new topics on my own.	☐	☐	☐	☐	☐
Even when tasks are difficult, I try to stick with them.	☐	☐	☐	☐	☐
I am open to new ways of doing familiar things.	☐	☐	☐	☐	☐
I tend to be motivated to work by assessment deadlines.	☐	☐	☐	☐	☐
I take responsibility for my learning experiences.	☐	☐	☐	☐	☐
I enjoy learning experiences.	☐	☐	☐	☐	☐

References

1. Akpan, J.P.; Andre, T. The Effect of a prior dissection simulation on middle school students' dissection performance and understanding of the anatomy and morphology of the frog. *J. Sci. Educ. Technol.* **2003**, *8*, 107–121. [CrossRef]
2. Martin, D.; McEvoy, B. Business simulations: A balanced approach to tourism education. *Int. J. Contemp. Hosp. Manag.* **2003**, *15*, 336–339. [CrossRef]
3. Pasin, F.; Giroux, H. The impact of a simulation game on operations management education. *Comput. Educ.* **2011**, *57*, 1240–1254. [CrossRef]
4. Stieff, M.; Wilensky, U. Connected Chemistry-Incorporating Interactive Simulations into the Chemistry Classroom. *J. Sci. Educ. Technol.* **2003**, *12*, 280–302. [CrossRef]
5. Raymond, C.; Usherwood, S. Assessment in simulations. *J. Political Sci. Educ.* **2013**, *9*, 157–167. [CrossRef]
6. Tao, Y.-H.; Wu, W.-N. Supplementing the review of business simulation games via bibliometrics analysis. In Proceedings of the 4th Multidisciplinary International Social Networks Conference on ZZZ—MISNC'17, Bangkok, Thailand, 17–19 July 2017.
7. Saputri, A.A. Student science process skills through the application of computer based scaffolding assisted by PhET simulation. *Taqaddum* **2021**, *13*, 21–38. [CrossRef]
8. Bonde, M.T.; Makransky, G.; Wandall, J.; Larsen, M.V.; Morsing, M.; Jarmer, H.; Sommer, M.O. Improving biotech education through gamified laboratory simulations. *Nat. Biotechnol.* **2014**, *32*, 694–697. [CrossRef]
9. Cetin, A. Effects of simulation based cooperative learning on physics achievement, science process skills, attitudes towards physics and usage of interactive whiteboards. *Kast. Eğitim Derg.* **2018**, *26*, 57–65.
10. de Jong, T.; van Joolingen, W.R. Scientific discovery learning with computer simulations of conceptual domains. *Rev. Educ. Res.* **1998**, *68*, 179–201. [CrossRef]
11. Huppert, J.; Lomask, S.M.; Lazarowitz, R. Computer simulations in the high school: Students' cognitive stages, science process skills and academic achievement in microbiology. *Int. J. Sci. Educ.* **2002**, *24*, 803–821. [CrossRef]
12. Hırça, N.; Bayrak, N. Education of gifted people with virtual physics laboratory: The subject of buoyancy. *J. Educ. Gift. Young Sci.* **2013**, *1*, 16–20.
13. Cayvaz, A.; Akcay, H.; Kapici, H.O. Comparison of simulation-based and textbook-based instructions on middle school students' achievement, inquiry skills and attitude. *Int. J. Educ. Math. Sci. Technol.* **2020**, *8*, 34–43. [CrossRef]
14. Supriyatman, S.; Sukarno, S. Improving science process skills (SPS) science concepts mastery (SCM) prospective student teachers through inquiry learning instruction model by using interactive computer simulation. *Int. J. Sci. Res.* **2014**, *3*, 6–9.
15. Siswanto, S.; Gumilar, S.; Yusiran, Y.; Trisnowati, E. Scientific approach-integrated virtual simulation: A physics learning design to enhance student's science process skills (sps). *Unnes Sci. Educ. J.* **2018**, *7*, 1. [CrossRef]
16. Finkelstein, N.; Adams, W.; Keller, C.; Perkins, K.; Wieman, C. Hightech tools for teaching physics: The physics education technology project. *Merlot J. Online Learn. Teach.* **2006**, *2*, 110–121.
17. Daskan, A.; Yildiz, Y. Blended learning: A potential approach to promote learning outcomes. *Int. J. Soc. Sci. Educ. Stud.* **2020**, *7*, 103–108.
18. Hoban, G.; Nielsen, W. Creating a narrated stop-motion animation to explain science: The affordances of "slowmation" for generating discussion. *Teach. Teach. Educ.* **2014**, *42*, 68–78. [CrossRef]
19. Price, A.; Wieman, C.; Perkins, K. Teaching with simulations. *Sci. Teach.* **2019**, *86*, 46–52. [CrossRef]
20. Lee, W.C.; Neo, W.L.; Chen, D.T.; Lin, T.B. Fostering changes in teacher attitudes toward the use of computer simulations: Flexibility, pedagogy, usability and needs. *Educ. Inf. Technol.* **2021**, *26*, 4905–4923. [CrossRef]
21. Hmelo, C.E.; Holton, D.L.; Kolodner, J.L. Designing to learn about complex systems. *J. Learn. Sci.* **2000**, *9*, 247–298. [CrossRef]
22. Tversky, B.; Bauer Morrisony, J.; Betrancourt, M. Animation: Can it facilitate? *Int. J. Hum.-Comput. Stud.* **2002**, *57*, 247–262. [CrossRef]
23. Plass, J.L.; Milne, C.; Homer, B.D.; Schwartz, R.N.; Hayward, E.O.; Jordan, T.; Barrientos, J. Investigating the effectiveness of computer simulations for chemistry learning. *J. Res. Sci. Teach.* **2012**, *49*, 394–419. [CrossRef]
24. Abdullah, S.; Syarif, A. The Effects of Inquiry-Based Computer Simulation with Cooperative Learning on Scientific Thinking and Conceptual Understanding of Gas Law. *Eurasia J. Math. Sci. Technol. Educ.* **2008**, *4*, 387–398. [CrossRef]
25. Smetana, L.K.; Bell, R.L. Computer simulations to support science instruction and learning: A critical review of the literature. *Int. J. Sci. Educ.* **2012**, *34*, 1337–1370. [CrossRef]
26. Terblanche, J.T. Using HCI principles to design interactive learning material. *Mediterr. J. Soc. Sci.* **2014**, *5*, 377. [CrossRef]

27. Murray-Smith, R.; Oulasvirta, A.; Howes, A.; Müller, J.; Ikkala, A.; Bachinski, M.; Fleig, A.; Fischer, F.; Klar, M. What simulation can do for HCI research. *Interactions* **2022**, *29*, 48–53. [CrossRef]
28. Jarvis, T.; Pell, A. *Secondary Pupils of Different Abilities Response to an e-Mission Simulation of the Montserrat Volcanic Eruption*; American Education Research Association: Montreal, CA, USA, 2005.
29. Chen, C.-H.; Howard, B. Effect of Live Simulation on Middle School Students' Attitudes and Learning toward Science. *Educ. Technol. Soc.* **2010**, *13*, 133–139.
30. Boyle, B.; Lamprianou, I.; Boyle, T. A longitudinal study of teacher change: What makes professional development effective? *Sch. Eff. Sch. Improv.* **2005**, *16*, 1–27. [CrossRef]
31. Coughlan, M.; Cronin, P.; Ryan, F. Survey research: Process and limitations. *Int. J. Ther. Rehabil.* **2009**, *16*, 9–15. [CrossRef]
32. Jeffries, P.R.; Rizzolo, M.A. *Designing and Implementing Models for the Innovative Use of Using Simulation to Teach Nursing Care of Ill Adults and Children: A National, Multi-Site, Multi-Method Study*; National League for Nursing: New York, NY, USA, 2006.
33. Lindgren, R.; Tscholl, M.; Wang, S.; Johnson, E. Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Comput. Educ.* **2016**, *95*, 174–187. [CrossRef]
34. Macaskill, A.; Taylor, E. The development of a brief measure of learner autonomy in university students. *Stud. High. Educ.* **2010**, *35*, 351–359. [CrossRef]
35. Pando-Garcia, J.; Periañez-Cañadillas, I.; Charterina, J. Business simulation games with and without supervision: An analysis based on the TAM model. *J. Bus. Res.* **2016**, *69*, 1731–1736. [CrossRef]
36. Soomro, K.A.; Jabeen, R. Investigating the Divide in Technology Uses by School Teachers. *J. Contemp. Trends Issues Educ.* **2022**, *2*, 1–23.
37. Abascal, J.; Azevedo, L. Fundamentals of inclusive HCI design. In Universal Access in Human Computer Interaction. In Proceedings of the Coping with Diversity: 4th International Conference on Universal Access in Human-Computer Interaction, UAHCI, Beijing, China, 22–27 July 2007; Springer: Berlin/Heidelberg, Germany, 2007. Part I 4. pp. 3–9.