International Journal of Education and Practice
2024 Vol. 12, No. 1, pp. 82-94
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/61.v12i1.3619

Application of regression decision tree and machine learning algorithms to examine students' online learning preferences during COVID-19 pandemic

Suwimon Kooptiwoot[1]
Sirirat Kooptiwoot[2]
Bagher Javadi[3+]

[1]*Department of Applied Sciences, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok, Thailand.*
Email: suwimon.ko@ssru.ac.th
[2]*Department of Psychiatry, Faculty of Medicine Siriraj Hospital, Mahidol University Bangkok, Thailand.*
Email: sirirat.koo@mahidol.ac.th
[3]*Department of Sciences, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok, Thailand.*
Email: Javadi.ba@ssru.ac.th

(+ Corresponding author)

Article History
Received: 21 July 2023
Revised: 24 October 2023
Accepted: 5 January 2024
Published: 29 January 2024

Keywords
COVID-19 pandemic
Decision tree
Machine learning
Multiple linear regression
Online studying
Student preferences.

ABSTRACT

The emergence of the novel coronavirus (COVID-19) profoundly disrupted the field of education, ushering in an era of widespread online learning adoption. This research paper seeks to investigate the multifaceted factors influencing students' preferences for online learning. Employing data exploration techniques and machine learning algorithms, the study aimed to identify the pivotal variables affecting students' willingness and performance in online educational environments. The research encompassed data collection through designated questionnaires and the application of decision tree-based machine learning algorithms to analyze these diverse factors. Through this approach, seven specific prerequisites were derived, employing multiple linear regression analysis within the decision tree framework, to illuminate the relationships between these factors. Key aspects considered in these prerequisites included factors such as "internet connectivity issues," "COVID-19 pandemic-induced stress," "COVID-19 vaccination status," and "close relatives' COVID-19 infections". Foremost among the reasons for students' reluctance to embrace online learning was the presence of "internet difficulties," including issues like slow connections and frequent disruptions. From the results of this research, it can be concluded that basic computer and internet courses can be beneficial for encouraging online education. Findings of this study underscore the potential benefits of offering basic computer and internet courses as a means to encourage and facilitate effective online education, particularly in the context of the COVID-19 pandemic.

Contribution/Originality: This research is one of the very few studies that focus on preferences of students for online study during the stressful conditions, their difficulties, and consequences. The regression decision tree based on machine learning algorithms would help the policy makers to find the possible consequences and conditional control statements as the prerequisites.

1. INTRODUCTION

The COVID -19 caused many health problems (such as cough, fever, muscle pain, sore throat, headache, loss of taste or smell, and difficult breathing) and brought a great impact on global lifestyle (Abu-Kaf, Nakash, Hayat, & Cohen, 2020; Ahmed et al., 2020; Alkhamees, Alrashed, Alzunaydi, Almohimeed, & Aljohani, 2020; Atchison et al., 2021; Babore et al., 2020). Daily life and many systems had huge challenges during this pandemic (Ahmed et al.,

2020). The unpredictability of the virus and its variants brought uncertainty to many activities in society. Increasing the distress associated with the pandemic forced the government to apply the lockdown rules and many distance regulations. Despite the effectiveness of the lockdown regulations and policies on decreasing the rate of mortality, it increased the society's distress (Alkhamees et al., 2020). Therefore, Quarantining had a profound impact on public health. During the pandemic, the education system had a great impact as transferring from on site to online learning.

The government policies and universities rules and regulations around the world forced the education system to switch from on-campus to online learning (Joshi, Vinay, & Bhaskar, 2021; Martin, Xie, & Bolliger, 2022; Mohalik & Sahoo, 2021; Oyedotun, 2020; Psotka, 2022; Winter, Costello, O'Brien, & Hickey, 2021). As this transformation had happened suddenly many instructors had faced a lot of challenges to prepare their lectures and students to use online tools. However, gradually online teaching and learning became the mainstream in the education system. In addition, education tools and systems evolved during the pandemic (Aslan, 2021; Batdı, Doğan, & Talan, 2021; Karakaya, Adigüzel, Üçüncü, Çimen, & Yilmaz, 2021; Liu, Lin, & Paas, 2022; Valverde-Berrocoso, Garrido-Arroyo, Burgos-Videla, & Morales-Cevallos, 2020; Winter et al., 2021).

Education tools and systems that were used and improved during pandemic were software products that mainly teachers used in their digital classrooms such as Google Classroom (Sudarsana, Putra, Astawa, & Yogantara, 2019), Pear Deck (Javed & Odhabi, 2018), Blackboard (Bradford, Porciello, Balkon, & Backus, 2007) and learning platforms such as Coursera (https://www.coursera.org/), CANVAS (https://www.canva.com/) and Khan Academy (https://www.khanacademy.org/). All these education tools and platforms were available online and were directly depending on the internet or other distance learning systems. On the other hand, the pandemic revealed many difficulties and problems in the ways performing the education and learning systems. There were dramatic challenges and many limitations on face-to-face education system, which inspired many to create tools and strategies to combat difficulties and fulfill necessities (Utomo, Sudayanto, & Saddhono, 2020). Most of the models in education and published research during the pandemic were about the intrinsic (factors) models toward online learning as a new technology (Holzer, Lüftenegger, Käser, et al., 2021; Holzer, Lüftenegger, Korlat, et al., 2021; Pelikan et al., 2021).

A dire need was felt to find the student preferences and the significance of the extrinsic variables during the pandemic. One of these important variables was stress, and its relation and interaction in adaptation and acceptance to the new technology. Furthermore, there was also a need to investigate the ease of use and usefulness of the new technology under stressful conditions, to examine the extent of adaptation with the new education system and the possibility of linking the learners' performances with their learning needs, for which the students' preferences should be uncovered. There was also a need to identify and investigate difficulties and behavioral changes of students during the pandemic and the subsequent lockdown (Alhumaid, Ali, Waheed, Zahid, & Habes, 2020; Husain, Idi, & Basri, 2020; Özüdoğru, 2021; Panda et al., 2020; Van Wart et al., 2020; Yan et al., 2021).

The current study investigated preferences of students for online study, their difficulties, and their consequences with a machine learning approach. The regression decision tree method of machine learning was applied to find the chances and possible consequences which could elaborate the algorithms that contained the conditional control statements as the rules. These rules were used to analyze the student decision preferences and help to identify a proper strategy to reach the better learning approach (Kaparthi & Bumblauskas, 2020; Somvanshi, Chavan, Tambade, & Shinde, 2016). This paper intended to bridge and introduce the gap of student preferences between online available tools towards designing the rational workflow to help students for enhancing learning experiences in COVID-19 and distance learning effectively and efficiently.

2. MATERIALS AND METHODS

In this research, Regression Decision Tree was utilized to explore students' preferences. This method, which was first introduced in 1984 (Zain & Herawan, 2014; Zhang, Zhao, & Yeom, 2020), involved using a decision tree algorithm to generate self-explanatory results for prediction purposes. It is considered a supervised machine learning

technique. By applying this method, we were able to predict the target variables, namely students' preferences, and estimate their values. The decision tree approach facilitated a better understanding of the results and enabled the prediction of students' preferences for online learning by utilizing decision trees and their associated values. The dataset, gathered from the collected questionnaires, exhibited homogeneity, allowing us to predict the influence of each variable. The resulting tree, derived from the regression analysis, demonstrated a simplistic, nonparametric, and nonlinear structure. Moreover, the most important variable was easily identified as the top node of the tree.

The data was collected through a questionnaire via the google forms (from September to November 2021) from a sample of 156 participants. The data was analyzed with Google Colab and SEE5 software. There were 10 attributes out of which nine were considered as the predictors and the last one was the outcome or response to nine predictors. Therefore, we can express the response variable (Yi) as a function of the predictors (Xi) and β coefficients, with the random noise (ei).

$$\Upsilon = f(Xi, \beta) + ei$$

The questions were designated as follows:

1. There is the internet problem with online studying. (3 answer options: yes, no, some)
2. There are problems with online studying. (3 answer options: yes, no, some)
3. Online learning environment. (2 answer options: home, cafe)
4. Got COVID-19 (2 answer options: yes, no)
5. Relatives got COVID-19 (2 answer options: yes, no)
6. Number of doses of COVID-19 vaccine received (number)
7. Fear of COVID-19 infection (2 answer options: yes, no)
8. Can be safe from COVID-19 (2 answer options: yes, no)
9. Stress during the COVID-19 pandemic (3 answer options: yes, no, some)
10. Prefer online learning (2 answer options: yes, no)

The last question was the target attribute.

Regression decision tree as one of the machine learning approaches was applied to analyze the student preferences. The identification tree as the machine learning method provided the final results about the students' decisions and preferences. The method is applied in many fields successfully especially in education research (Chen, Goo, & Shen, 2014; Mienye, Sun, & Wang, 2019; Navada, Ansari, Patil, & Sonkamble, 2011; Venkatasubramaniam et al., 2017; Xu & Yin, 2021; Yang, 2022; Yang, 2021; Zhang et al., 2020). The method provided the results in the form of decisions with both classification and regression in machine learning. The simplicity of final results was one of the great advantages of this method (Chen et al., 2014; Hou, Hou, Shi, Wang, & Yuan, 2014; Huynh-Cam, Chen, & Le, 2021; Song & Ying, 2015; Wang & Wu, 2020; Zhou & Fujita, 2017).

3. RESULTS

The results showed that 120 students did not like to study online. In other words, online learning was not their first choice. The distribution plot is shown in Figure 1-A. The relationship between dose of vaccination and their preferences is shown in Figure 1-B. The results show that vaccinations did not play a significant role in preferences of online studying. The pairwise relationship shown in Figure 1-B. clearly visualizes the role of vaccination in the students who did not prefer to study online (orange color), although they had got their COVID-19 vaccinations.

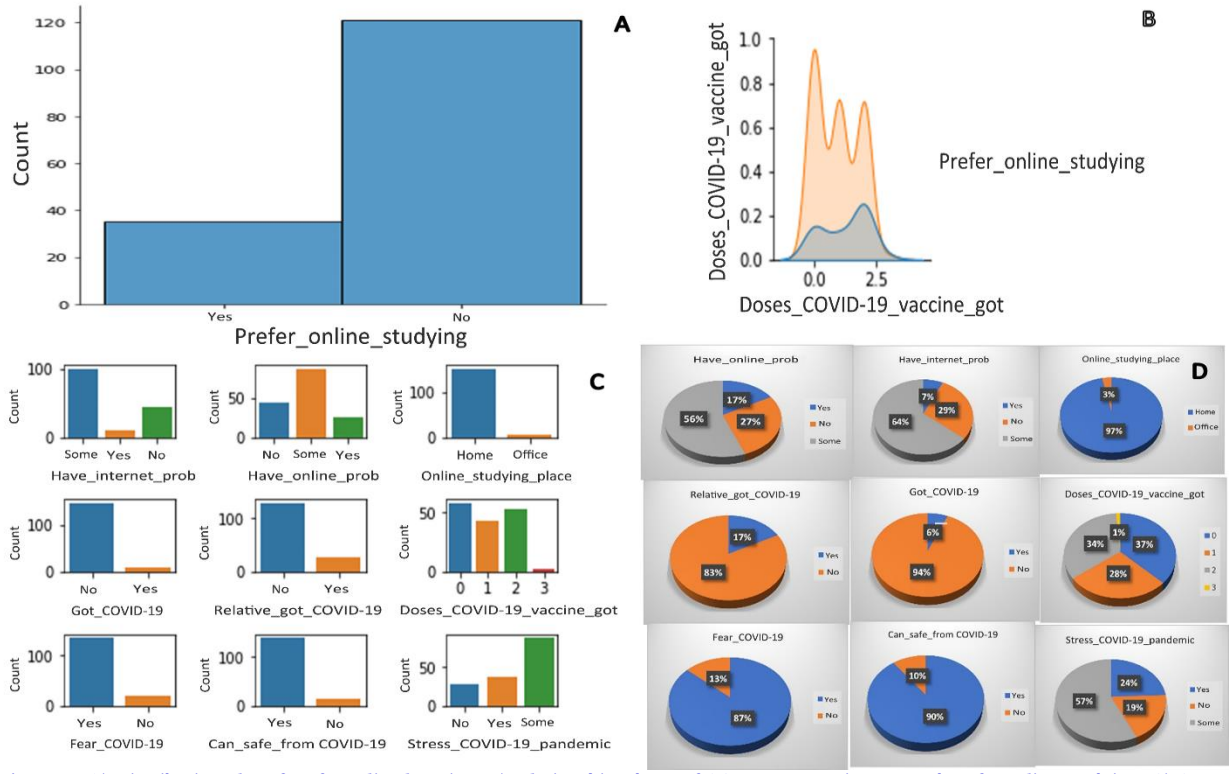

Figure 1. A) Distribution plot of prefer online learning, B) relationships doses of COVID-19 vaccine got and prefer online studying, C) Count of each attribute's answers, D) Percentage of each answer of each attribute.

Seventy one percent of students (64% had some while 7% had major) faced internet problems. Internet signal was the most important factor to influence online learning, since whenever the internet signal was not stable, it created a major obstacle in online learning. The results showed that approximately 73% of students had online problems (56% had some and 17% had major). Online problems caused several issues that forced students not to prefer online learning, including non-accessibility of a strong internet connection at home, and being at home made most students were busy in their family supporting work. The results revealed that 97% of students found home as the main place for online learning compared to other places such as café. This showed that most students had the internet but the quality of the internet such as signal or speed was the main reason that they did not prefer to study online. Most students (94%) did not suffer from COVID-19 which showed that they could save themselves effectively and they had enough public health training. This fact was repeated with the results of their relatives, although 83% of students did not have relatives with COVID-19 infection.

Vaccination rate among the students was quite good as only 37% of students did not get the COVID-19 vaccine. Most students (87%) feared COVID-19 infection. Protection against COVID 19 was interesting too as a majority of students (90%) thought that they could protect themselves from COVID-19 infection. This can be indirectly proved that training and the knowledge of protection could satisfy them to feel they could protect themselves very well. The pandemic also made most students stressed (81%). Finally, most of the students did not prefer to study online (only 22% of students preferred online learning).

The machine learning application obtained seven prerequisites showing the relationships among related attributes and preferences for online study Figure 1-C and D. The error rate was 17.9 %. These prerequisites were classified into two types: The first type (05 prerequisites) did not favor online studying, while the second type (02 prerequisites) did prefer online studying.

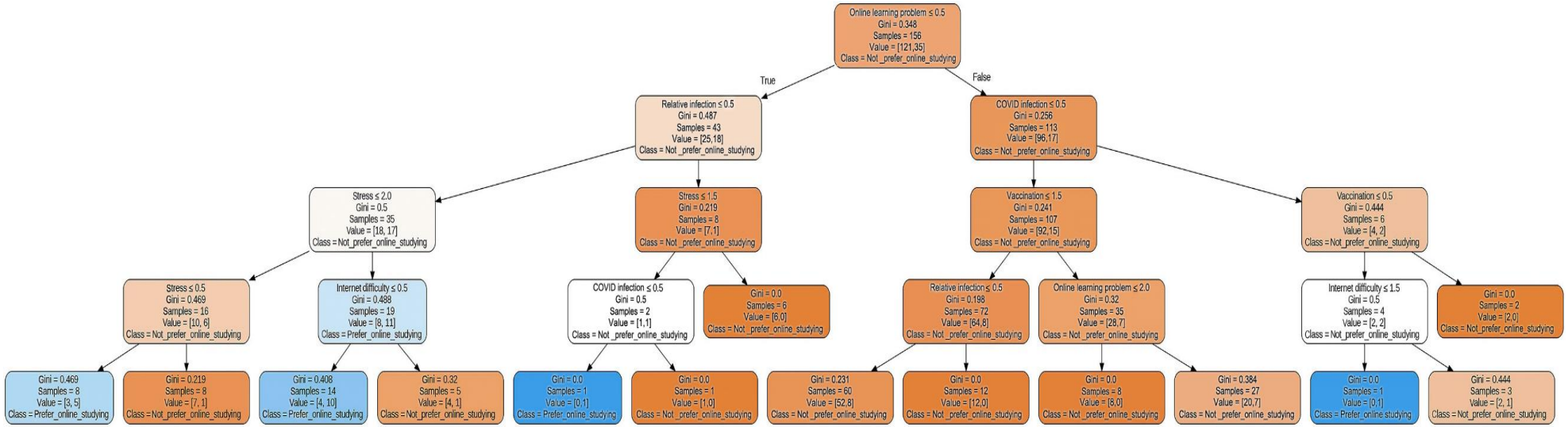

Figure 2. Decision tree of student online preferences.

(I) Students that preferred online studying:

Prerequisite 1: did not have internet problem, got 2 doses of COVID-19 vaccine, did not have any stress from COVID-19 pandemic.

Prerequisite 2: did not have internet problem, no relative got COVID-19, had some stress from COVID-19 pandemic

((II) Students that did not prefer online studying.

Prerequisite 3: Had major internet problem.

Prerequisite 4: Did not have internet problem, but had stress from COVID-19 pandemic.

Prerequisite 5: Did not get COVID-19 vaccine, no stress from COVID-19 pandemic.

Prerequisite 6: Had relative with COVID-19, and got some stress from COVID-19 pandemic.

Prerequisite 7: Had some internet problem.

The knowledge gained from machine learning application showed that students preferred online studying based on the stability of the internet (Figure 2). From Prerequisite 1, no stress from the COVID-19 pandemic, and they already had two doses of vaccine, showed that they felt well protected from COVID-19 and they did not have any stress from the COVID-19 pandemic. From Prerequisite 2, some stress from the COVID-19 pandemic; no relatives got COVID, but they were fine with online studying due to no internet problem. The results here provide the fact that having no problem in internet connection was the main reason that students preferred online studying. This fact was more clearly seen in the second class of students who did not prefer online studying.

The prerequisites in the second class showed that the students who had major internet problems (or some) were unable to study online perfectly. Thus, they did not prefer online study. For Prerequisite 4, even though some students did not have internet problems, they had stress from the COVID-19 pandemic that made them unable to spend their normal lives as usual. Therefore, stress was the second reason that could not let them focus on online studying. For sure on-site study could help them to decrease their stress. Another annotation from the rules above can be explained as they got some stress from the COVID-19 pandemic, and also their relatives got COVID-19. This means that COVID-19 had unfortunately infected them or their family or relatives and made them more stressful to study online at home. It is interesting to mention that all students had an internet connection, but still their connection and their usability of the internet were the main reason that they did not prefer online study. Here, it is important to mention that classroom management and different techniques in online classes can play a vital role to help students attract to online learning.

Online education during the COVID-19 pandemic saw a multidisciplinary usage of computational technology that needed knowledge and skills to understand and perform the learning process (Wissing, Hilverda, Scheepers, Nieboer, & Vollmann, 2022). The most important challenge to learn in this system is the complexity of workflow (Lobos et al., 2022). Teachers and students need to understand several concepts in computational technology, especially the internet and communication to build a successful learning model. Therefore, suitable, and proper learning materials are necessary to fulfill the learning process.

Online education is one of the new fields in Science, Technology, Engineering and Mathematics education (Bybee, 2013; Cavanaugh, Jacquemin, & Junker, 2022). This field of study combines the learning process with the help of computers. The internet, computer and teacher are the main subjects that cover learning in a wide scope of integration of two major fields, educational system and computational internet technology. Students need to acquire the knowledge from a distance and combine and aggregate them. These combined concepts Manouselis, Drachsler, Vuorikari, Hummel, and Koper (2011) made online learning a challenging subject to teach and learn (Honey, 2013). The complexity of analyzing and modeling this kind of education includes familiarity with basic computational and multimedia technology for both teachers and students as well as education models/strategies scheduling and resource management (Allam et al., 2022).

This can be difficult at the introductory level of teaching and learning; however, proper educational tools and guidelines can effectively and efficiently help in teaching via visualization and simulation the concept to develop students' understanding and confidence. Therefore, organized courses and tools play a vital role to facilitate the learning and teaching process. It is very difficult for one to overcome the lack of suitable guidelines to find and apply the educational learning system and materials on their own with lack of prior information. Therefore, learning about the students' preferences and needs can be fulfilled with proper available tools (Corbu & Edelhauser, 2021; Ishimaru et al., 2021).

4. DISCUSSION

The COVID-19 pandemic has brought about the widespread adoption of online education, which encompasses a multidisciplinary application of computational technology. Engaging in this form of education requires a certain level of knowledge and skills to navigate and effectively participate in the learning process (Wissing et al., 2022). Among the key challenges faced in this system is the complexity of the workflow, which can be demanding for both teachers and students (Lobos et al., 2022). To succeed in this online learning environment, it is crucial for educators and learners to grasp various concepts related to computational technology, particularly those pertaining to internet usage and communication. Furthermore, the availability of suitable and appropriate learning materials is essential for facilitating a productive learning experience.

Our study clearly revealed the importance of extrinsic variables and factors (such as COVID-19 stress) on preferences online study by learners. In previous educational models, the focus of adaptation to new technology predominantly revolved around identifying the impact of intrinsic variables on online learning. Technology acceptance models Granić and Marangunić (2019) have attempted to uncover these intrinsic factors and can greatly benefit from our study. Many studies have emphasized the importance of classroom management variables in enhancing student preferences for online learning. However, the unprecedented circumstances and stressful situations brought about by the pandemic disrupted the usual patterns. Factors such as ease of use and usefulness, which have been extensively investigated in various contexts, may not necessarily apply in the same way under these unique circumstances (Gurban & Almogren, 2022).

The success of the education system heavily relies on the accessibility of the internet and the computer literacy and communication skills of both students and instructors as our results showed. This is consistent with previous research that primarily focused on identifying variables directly and indirectly related to classroom management (Jie & Ali, 2021; Sepulveda-Escobar & Morrison, 2020). However, it is important to recognize that there is a preceding factor to classroom management that can significantly impact the learning experience: human stress, particularly in pandemic conditions. To address this issue, it is crucial to employ suitable strategies that incorporate asynchronous types of software and platforms for delivering teaching materials. The time lag provided by asynchronous learning allows learners to access and study the materials at more convenient and suitable times, mitigating the stress associated with real-time online learning and internet difficulties. Game-based learning, such as the utilization of serious games and Massive Multiplayer Online Role-Playing Games (MMORPG), is an effective example of classroom management. These approaches not only accommodate the time lag but also assist in overcoming disconnections and internet-related challenges. This study found that game-based learning contributes to reducing stress by creating engaging and enjoyable classroom environments, which is consistent with recent studies that have presented and reviewed numerous successful examples of game-based learning (Tavares, 2022).

Our results clearly emphasized that analyzing and modeling online learning is complex and encompasses various aspects, including a solid understanding of computational and multimedia technology for both teachers and students. This is sustained by the fact that online education has emerged as a distinct field within Science, Technology, Engineering, and Mathematics (STEM) education (Bybee, 2013; Cavanaugh et al., 2022; Zhai, 2019). This field integrates the learning process with the use of computers, encompassing the internet, computers, and teachers as the

central components. It involves the integration of two major domains: the educational system and computational internet technology. In online learning, students are required to acquire knowledge remotely and then combine and synthesize it. The combination of these concepts presents a significant challenge in teaching and learning (Honey, 2013).

Additionally, online learning involves the development of effective education models, strategies for scheduling, and resource management (Allam et al., 2022). The integration of these elements is crucial to ensure a successful online learning experience. Teachers and students need to be proficient in using basic computational and multimedia tools to facilitate effective instruction and learning. Moreover, online education requires careful consideration of scheduling and resource management to ensure the seamless delivery of content and resources to students. This includes organizing and optimizing the availability of learning materials, assessments, and interactive activities to enhance the learning experience. online education represents a dynamic field that merges the educational system with computational internet technology. It presents unique challenges, such as fostering effective teaching and learning in a remote environment and addressing the complexities of managing resources and schedules. Proficiency in computational technology and education models is vital for successful implementation and optimization of online learning.

Teaching and learning at the introductory level can present challenges, but with the right educational tools and guidelines, these challenges can be effectively addressed. Visualization and simulation techniques can play a crucial role in teaching complex concepts, enabling students to develop a deeper understanding and enhance their confidence in the subject matter. Properly organized courses and tools are essential in facilitating the teaching and learning process, providing students with the necessary resources and support.

When it comes to implementing effective teaching strategies, it can be overwhelming for educators to navigate the vast landscape of educational materials and learning systems without suitable guidelines. Having access to well-structured courses and tools becomes critical in overcoming these obstacles. They provide educators with a framework and direction, enabling them to design engaging and impactful learning experiences. Additionally, having a repository of proper guidelines empowers educators to select and apply the most relevant and effective materials for their students' needs.

Understanding students' preferences and needs is crucial in creating an optimal learning environment. By utilizing appropriate tools and resources, educators can gather valuable insights into students' learning preferences, allowing them to tailor their instruction accordingly. This approach promotes a student-centered learning experience, enhancing engagement and overall educational outcomes (Corbu & Edelhauser, 2021; Ishimaru et al., 2021). Thus, having access to suitable educational tools and guidelines is vital in overcoming the challenges of teaching and learning at the introductory level. Visualization and simulation techniques can enhance student understanding and confidence. Well-organized courses and tools provide a framework for effective instruction, while understanding students' preferences enables educators to create personalized learning experiences. By leveraging proper tools and guidelines, educators can foster a supportive and engaging learning environment.

Many tools and techniques in Technology Enhanced Learning (TEL) facilitate the course modules and study subjects in the education sector (Manouselis et al., 2011). Computer tools make the learning process usable, efficient and interactive. Many studies reported the use of computer aided tools and models that made good progress in education especially in biology (Mor & Winters, 2007).

Studies have reported that psychologically in education, mastering the challenges and overcoming them can be achieved by motivation (Alexander & Winne, 2012). This motivation can highlight the value of academic achievement and relevant expectation Likewise, Biggs and Collis (1989) illustrate the constructive alignment to restructure the intended learning outcomes (ILOs) with teaching and learning activities (TLAs) and assessment tasks (TAs) These constructive alignments can motivate students by understanding the objectives, form of participation and expected results during the module learning. Thus, application of tool support plays a vital role in students' learning.

Furthermore, researchers have reported that appropriate tools and resources made substantial improvement in learning complex concepts (Abaci, Robertson, Linklater, & McNeill, 2021).

Generally, E-learning for teaching is presented via four phases that includes content development, instructional phase, multimedia /web design phase and testing / execution phase (Cho & Woo, 2022). Thus, multimedia is an important tool in this process. It is noteworthy to mention that cognitive theory of multimedia learning presents three stages (sensory memory, working memory and long-term memory) as the learning pattern of the students. Most students have three kinds of loads (intrinsic, germane and extraneous) due to the complexity of the subject. Therefore, the visual support tools can play a vital role among other factors to improve the student's learning (Brame, 2016).

These days many online tools try to offer to teach in many subjects however usability of them is challenging to conduct learning sessions in the classroom. Most of them are not free of charge or installed easily especially for new learners with limited knowledge. Furthermore, they mostly lack comprehensive support. With the help of Kolb's experiential learning framework (Kolb, 1984) that includes four cyclic steps; Abstract Conceptualization, Active Experimentation, Concrete Experience and Reflective Observation, this research offers the clear obstacles and distress for students and eventually the guideline to cover the theoretical and practical aspects of online educational model for students learning activities.

5. CONCLUSION

A regression analysis of the responses from questionnaires of 156 students was done. The designated questions in the survey showed students' preferences of online learning during COVID 19 pandemic. From this research, the estimation of conditional expectation of students' preferences from all independent responses provided seven prerequisites depicted as the decision tree. The information provided here could be widely used for prediction of different techniques to apply for online class management. Furthermore, the aim of the learning system would have a substantial impact on student's preferences. The results of this research would be applicable to other geographical regions with some caution as the technological knowledge and internet availability might be different.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Suan Sunandha Rajabhat University, Thailand has granted approval for this study (Ref. No. COE.2-012).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abaci, S., Robertson, J., Linklater, H., & McNeill, F. (2021). Supporting school teachers' rapid engagement with online education. *Educational Technology Research and Development, 69*, 29-34. https://doi.org/10.1007/s11423-020-09839-5

Abu-Kaf, S., Nakash, O., Hayat, T., & Cohen, M. (2020). Emotional distress among the Bedouin Arab and Jewish elderly in Israel: The roles of gender, discrimination, and self-esteem. *Psychiatry Research, 291*, 113203. https://doi.org/10.1016/j.psychres.2020.113203

Ahmed, M. Z., Ahmed, O., Aibao, Z., Hanbin, S., Siyu, L., & Ahmad, A. (2020). Epidemic of COVID-19 in China and associated psychological problems. *Asian Journal of Psychiatry, 51*, 102092. https://doi.org/10.1016/j.ajp.2020.102092

Alexander, P. A., & Winne, P. H. (2012). *Handbook of educational psychology* (2nd ed.). New York: Routledge.

Alhumaid, K., Ali, S., Waheed, A., Zahid, E., & Habes, M. (2020). COVID-19 & elearning: Perceptions & attitudes of teachers towards E-learning acceptancein the developing countries. *Multicultural Education, 6*(2), 100-115.

Alkhamees, A. A., Alrashed, S. A., Alzunaydi, A. A., Almohimeed, A. S., & Aljohani, M. S. (2020). The psychological impact of COVID-19 pandemic on the general population of Saudi Arabia. *Comprehensive Psychiatry, 102*, 152192. https://doi.org/10.1016/j.comppsych.2020.152192

Allam, H., Alghamdi, N. K., Alghamdi, S. A., Alzaedi, A. A., Alharthi, H. A., & Elsayyad, L. K. (2022). Medical undergraduate students' perception about online education during the COVID-19 pandemic. *Open Access Macedonian Journal of Medical Sciences, 10*(E), 213-218. https://doi.org/10.3889/oamjms.2022.8024

Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers & Education, 171*, 104237. https://doi.org/10.1016/j.compedu.2021.104237

Atchison, C., Bowman, L. R., Vrinten, C., Redd, R., Pristerà, P., Eaton, J., & Ward, H. (2021). Early perceptions and behavioural responses during the COVID-19 pandemic: A cross-sectional survey of UK adults. *BMJ Open, 11*(1), e043577. https://doi.org/10.1136/bmjopen-2020-043577

Babore, A., Lombardi, L., Viceconti, M. L., Pignataro, S., Marino, V., Crudele, M., . . . Trumello, C. (2020). Psychological effects of the COVID-2019 pandemic: Perceived stress and coping strategies among healthcare professionals. *Psychiatry Research, 293*, 113366. https://doi.org/10.1016/j.psychres.2020.113366

Batdı, V., Doğan, Y., & Talan, T. (2021). Effectiveness of online learning: A multi-complementary approach research with responses from the COVID-19 pandemic period. *Interactive Learning Environments*, 1-34. https://doi.org/10.1080/10494820.2021.1954035

Biggs, J., & Collis, K. (1989). Towards a model of school-based curriculum development and assessment using the SOLO taxonomy. *Australian Journal of Education, 33*(2), 151-163. https://doi.org/10.1177/168781408903300205

Bradford, P., Porciello, M., Balkon, N., & Backus, D. (2007). The Blackboard learning system: The be all and end all in educational instruction? *Journal of Educational Technology Systems, 35*(3), 301-314.

Brame, C. J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE—Life Sciences Education, 15*(4), 1-6. https://doi.org/10.1187/cbe.16-03-0125

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. Arlington, Virginia: National Science Teachers Association Press.

Cavanaugh, J., Jacquemin, S. J., & Junker, C. R. (2022). Variation in student perceptions of higher education course quality and difficulty as a result of widespread implementation of online education during the COVID-19 pandemic. *Technology, Knowledge and Learning*, 1-16. https://doi.org/10.1007/s10758-022-09596-9

Chen, S., Goo, Y.-J. J., & Shen, Z.-D. (2014). A hybrid approach of stepwise regression, logistic regression, support vector machine, and decision tree for forecasting fraudulent financial statements. *The Scientific World Journal, 14*, 968712. https://doi.org/10.1155/2014/968712

Cho, Y. Y., & Woo, H. (2022). Factors in evaluating online learning in higher education in the era of a new normal derived from an Analytic Hierarchy Process (AHP) based survey in South Korea. *Sustainability, 14*(5), 3066. https://doi.org/10.3390/su14053066

Corbu, E. C., & Edelhauser, E. (2021). Responsive dashboard as a component of learning analytics system for evaluation in emergency remote teaching situations. *Sensors, 21*(23), 7998. https://doi.org/10.3390/s21237998

Granić, A., & Marangunić, N. (2019). Technology acceptance model in educational context: A systematic literature review. *British Journal of Educational Technology, 50*(5), 2572-2593.

Gurban, M. A., & Almogren, A. S. (2022). Students' actual use of E-learning in higher education during the COVID-19 pandemic. *Sage Open, 12*(2), 21582440221091250.

Holzer, J., Lüftenegger, M., Käser, U., Korlat, S., Pelikan, E., Schultze-Krumbholz, A., & Schober, B. (2021). Students' basic needs and well-being during the COVID-19 pandemic: A two-country study of basic psychological need satisfaction, intrinsic learning motivation, positive emotion and the moderating role of self-regulated learning. *International Journal of Psychology, 56*(6), 843-852.

Holzer, J., Lüftenegger, M., Korlat, S., Pelikan, E., Salmela-Aro, K., Spiel, C., & Schober, B. (2021). Higher education in times of COVID-19: University students' basic need satisfaction, self-regulated learning, and well-being. *Aera Open*, *7*, 23328584211003164.

Honey, M. (2013). *Design, make, play: Growing the next generation of STEM innovators*. New York: Routledge.

Hou, S., Hou, R., Shi, X., Wang, J., & Yuan, C. (2014). Research on C5. 0 algorithm improvement and the test in lightning disaster statistics. *International Journal of Control and Automation*, *7*(1), 181-190. https://doi.org/10.14257/ijca.2014.7.1.15

Husain, B., Idi, Y. N., & Basri, M. (2020). Teachers' perceptions on adopting E-learning during COVID-19 outbreaks; advantages, disadvantages, suggestions. *Jurnal Tarbiyah*, *27*(2), 41-57.

Huynh-Cam, T.-T., Chen, L.-S., & Le, H. (2021). Using decision trees and random forest algorithms to predict and determine factors contributing to first-year university students' learning performance. *Algorithms*, *14*(11), 318. https://doi.org/10.3390/a14110318

Ishimaru, D., Adachi, H., Nagahara, H., Shirai, S., Takemura, H., Takemura, N., . . . Ikeda, M. (2021). Characteristics of adaptation in undergraduate university students suddenly exposed to fully online education during the COVID-19 pandemic. *Frontiers in Psychiatry*, *12*, 731137. https://doi.org/10.3389/fpsyt.2021.731137

Javed, Y., & Odhabi, H. (2018). *Active learning in classrooms using online tools: Evaluating Pear-Deck for students' engagement*. Paper presented at the 2018 Fifth HCT Information Technology Trends (ITT).

Jie, C., & Ali, N. M. (2021). COVID-19: What are the challenges of online learning? A literature review. *International Journal of Advanced Research in Future Ready Learning and Education*, *23*(1), 23-29.

Joshi, A., Vinay, M., & Bhaskar, P. (2021). Impact of coronavirus pandemic on the Indian education sector: Perspectives of teachers on online teaching and assessments. *Interactive Technology and Smart Education*, *18*(2), 205-226. https://doi.org/10.1108/itse-06-2020-0087

Kaparthi, S., & Bumblauskas, D. (2020). Designing predictive maintenance systems using decision tree-based machine learning techniques. *International Journal of Quality & Reliability Management*, *37*(4), 659-686. https://doi.org/10.1108/ijqrm-04-2019-0131

Karakaya, F., Adigüzel, M., Üçüncü, G., Çimen, O., & Yilmaz, M. (2021). Teachers' views towards the effects of Covid-19 pandemic in the education process in Turkey. *Participatory Educational Research*, *8*(2), 17-30. https://doi.org/10.17275/per.21.27.8.2

Kolb, D. A. (1984). *Experience as the source of learning and development*. Upper Sadle River: Prentice Hall.

Liu, T.-C., Lin, Y.-C., & Paas, F. (2022). A new application of the temporal contiguity effect in designing narrated slideshows. *Educational Technology Research and Development*, *70*(1), 59-72. https://doi.org/10.1007/s11423-021-10076-7

Lobos, K., Cobo-Rendón, R., Mella-Norambuena, J., Maldonado-Trapp, A., Fernández Branada, C., & Bruna Jofré, C. (2022). Expectations and experiences with online education during the COVID-19 pandemic in university students. *Frontiers in Psychology*, *12*, 815564. https://doi.org/10.3389/fpsyg.2021.815564

Manouselis, N., Drachsler, H., Vuorikari, R., Hummel, H. G. K., & Koper, R. (2011). Recommender systems in technology enhanced learning. In P. B. Kantor, F. Ricci, L. Rokach, & B. Shapira (Eds.), Recommender Systems Handbook. In (pp. 387-415). Berlin: Springer.

Martin, F., Xie, K., & Bolliger, D. U. (2022). Engaging learners in the emergency transition to online learning during the COVID-19 pandemic. *Journal of Research on Technology in Education*, *54*(Sup1), S1-S13. https://doi.org/10.1080/15391523.2021.1991703

Mienye, I. D., Sun, Y., & Wang, Z. (2019). Prediction performance of improved decision tree-based algorithms: A review. *Procedia Manufacturing*, *35*, 698-703. https://doi.org/10.1016/j.promfg.2019.06.011

Mohalik, R., & Sahoo, S. (2021). Accessibility, competency and perception of school teachers towards online teaching in the midst of COVID-19 pandemic. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3791919

Mor, Y., & Winters, N. (2007). Design approaches in technology-enhanced learning. *Interactive Learning Environments*, *15*(1), 61-75. https://doi.org/10.1080/10494820601044236

Navada, A., Ansari, A. N., Patil, S., & Sonkamble, B. A. (2011). *Overview of use of decision tree algorithms in machine learning*. Paper presented at the 2011 IEEE Control and System Graduate Research Colloquium.

Oyedotun, T. D. (2020). Sudden change of pedagogy in education driven by COVID-19: Perspectives and evaluation from a developing country. *Research in Globalization*, *2*, 100029. https://doi.org/10.1016/j.resglo.2020.100029

Özüdoğru, G. (2021). Problems faced in distance education during Covid-19 Pandemic. *Participatory Educational Research*, *8*(4), 321-333. https://doi.org/10.17275/per.21.92.8.4

Panda, D. S., Gamal, M., Zafar, A., Senapati, A. K., Patro, S. K., Sahoo, P. K., & Bose, A. (2020). A study on the effectiveness of online teaching in pharmacy education from teacher and student perspectives during the COVID-19 pandemic. *Pharmacy Education*, *20*(2), 297-301. https://doi.org/10.46542/pe.2020.202.297301

Pelikan, E. R., Korlat, S., Reiter, J., Holzer, J., Mayerhofer, M., Schober, B., & Chen, J. (2021). Distance learning in higher education during COVID-19: The role of basic psychological needs and intrinsic motivation for persistence and procrastination–a multi-country study. *PLoS One*, *16*(10), e0257346.

Psotka, J. (2022). Exemplary online education: For whom online learning can work better. *Interactive Learning Environments 30*(2), 199-201. https://doi.org/10.1080/10494820.2022.2031065

Sepulveda-Escobar, P., & Morrison, A. (2020). Online teaching placement during the COVID-19 pandemic in Chile: Challenges and opportunities. *European Journal of Teacher Education*, *43*(4), 587-607.

Somvanshi, M., Chavan, P., Tambade, S., & Shinde, S. V. (2016). *A review of machine learning techniques using decision tree and support vector machine*. Paper presented at the 2016 International Conference on Computing Communication Control and Automation (ICCUBEA).

Song, Y.-Y., & Ying, L. (2015). Decision tree methods: Applications for classification and prediction. *Shanghai Archives of Psychiatry*, *27*(2), 130-135.

Sudarsana, I. K., Putra, I. B. M. A., Astawa, I. N. T., & Yogantara, I. W. L. (2019). The use of Google classroom in the learning process. *In Journal of Physics: Conference Series (Vol. 1175, p. 012165). IOP Publishing*.

Tavares, N. (2022). The use and impact of game-based learning on the learning experience and knowledge retention of nursing undergraduate students: A systematic literature review. *Nurse Education Today*, 105484.

Utomo, M. N. Y., Sudayanto, M., & Saddhono, K. (2020). Tools and strategy for distance learning to respond COVID-19 pandemic in Indonesia. *Ingénierie des Systèmes d'Information*, *25*(3), 383-390.

Valverde-Berrocoso, J., Garrido-Arroyo, M. D. C., Burgos-Videla, C., & Morales-Cevallos, M. B. (2020). Trends in educational research about e-learning: A systematic literature review (2009–2018). *Sustainability*, *12*(12), 5153. https://doi.org/10.3390/su12125153

Van Wart, M., Ni, A., Medina, P., Canelon, J., Kordrostami, M., Zhang, J., & Liu, Y. (2020). Integrating students' perspectives about online learning: A hierarchy of factors. *International Journal of Educational Technology in Higher Education*, *17*(1), 1-22. https://doi.org/10.1186/s41239-020-00229-8

Venkatasubramaniam, A., Wolfson, J., Mitchell, N., Barnes, T., JaKa, M., & French, S. (2017). Decision trees in epidemiological research. *Emerging Themes in Epidemiology*, *14*, 1-12. https://doi.org/10.1186/s12982-017-0064-4

Wang, G., & Wu, N. (2020). Keywords: Students' learning performance; prediction model; random forest (RF); decision tree (DT); feature selection; technological and vocational education. *IEEE Access*, *8*, 39747-39757.

Winter, E., Costello, A., O'Brien, M., & Hickey, G. (2021). Teachers' use of technology and the impact of Covid-19. *Irish Educational Studies*, *40*(2), 235-246. https://doi.org/10.1080/03323315.2021.1916559

Wissing, R., Hilverda, F., Scheepers, R., Nieboer, A., & Vollmann, M. (2022). Peer relationships buffer the negative association of online education with education satisfaction and subsequently with study engagement among undergraduate medical students. *BMC Medical Education*, *22*(1), 276. https://doi.org/10.1186/s12909-022-03337-3

Xu, Q., & Yin, J. (2021). Application of random forest algorithm in physical education. *Scientific Programming*, *2021*, 1-10. https://doi.org/10.1155/2021/1996904

Yan, L., Whitelock-Wainwright, A., Guan, Q., Wen, G., Gašević, D., & Chen, G. (2021). Students' experience of online learning during the COVID-19 pandemic: A province-wide survey study. *British Journal of Educational Technology, 52*(5), 2038-2057. https://doi.org/10.1111/bjet.13102

Yang, F. (2022). Construction of graduate behavior dynamic model based on dynamic decision tree algorithm. *Discrete Dynamics in Nature and Society, 2022*, 1-10. https://doi.org/10.1155/2022/3684176

Yang, Y. (2021). The evaluation of online education course performance using decision tree mining algorithm. *Complexity, 2021*, 1-13. https://doi.org/10.1155/2021/5519647

Zain, J. M., & Herawan, T. (2014). Data mining for education decision support: A review. *International Journal of Emerging Technologies in Learning, 9*(6), 4.

Zhai, L. (2019). A inquiry teaching mode based on STEM education. *International Journal of Emerging Technologies in Learning, 14*(17), 44. https://doi.org/10.3991/ijet.v14i17.11204

Zhang, Z., Zhao, Z., & Yeom, D.-S. (2020). Decision tree algorithm-based model and computer simulation for evaluating the effectiveness of physical education in universities. *Complexity, 2020*, 1-11. https://doi.org/10.1155/2020/8868793

Zhou, L., & Fujita, H. (2017). Posterior probability based ensemble strategy using optimizing decision directed acyclic graph for multi-class classification. *Information Sciences, 400*, 142-156. https://doi.org/10.1016/j.ins.2017.02.059