

# Enhancing Personalized Education through an Adaptive Framework: Assessing the Impact of an Optimized Planning Generator

**Selwa Elfirdoussi**

EMINES, University Mohammed VI Polytechnic, Ben Guerir, Morocco  
selwa.elfirdoussi@emines.um6p.ma (corresponding author)

**Hind Kabaili**

SID Department, ISCAE Group, Casablanca, Morocco  
hkaibali@groupeiscae.ma

**Najoua Alaoui**

EMINES, University Mohammed VI Polytechnic, Ben Guerir, Morocco  
najoua.alaoui@emines.um6p.ma

**Larbi El Firdoussi**

Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakesh, Morocco  
elfirdoussi@uca.ac.ma

Received: 29 October 2024 | Revised: 22 November 2024 | Accepted: 28 November 2024

Licensed under a CC-BY 4.0 license | Copyright (c) by the authors | DOI: <https://doi.org/10.48084/etasr.9438>

## ABSTRACT

The COVID-19 crisis has exposed the inefficiencies of many e-learning platforms, highlighting the importance of face-to-face interactions between students and professors. To address these challenges, this study proposes an adaptive blended learning framework that considers the unique profiles of students, professors, and university policies. The proposed framework consists of three main components: (i) a program generator that generates a list of sessions with an optimal blend of face-to-face and e-learning modes, (ii) an evaluation model that proposes scheduling planning that is optimal for both students and professors, and (iii) an AI model that predicts student engagement in courses using the output of the evaluation model.

*Keywords-adaptative e-learning; blended learning; learning framework; artificial intelligence model*

## I. INTRODUCTION

The educational system in Morocco relied on traditional classroom education, and students were required to attend classes in person. However, in March 2020, in response to the lockdown, Moroccan universities abruptly switched to distance learning without a well-planned approach [1]. This sudden change caused unprecedented adjustments, resulting in a forced shift to online learning. Unfortunately, professors did not have enough time to adjust to the new teaching methods or institutions to adapt their programs to fit the new platforms. This abrupt transition has radically transformed the field of higher education, with new technologies, their adoption, acceptance, and other areas that bridge the gap between higher education and the new and disruptive technologies being investigated.

In recent years, many universities have been looking for innovative ways to teach, using e-learning platforms [2]. Instead of focusing on the negative effects of the pandemic, it is essential to identify its positive effects. Students have embraced the changes introduced by online learning, increasing their accountability and ability to learn independently. This situation also helped most lecturers to keep up with the qualitative transformation of studies [3]. Previous studies on the assessment of distance learning in higher education during the COVID-19 pandemic illustrated the limitations of the newly employed methods in the Moroccan educational system. A qualitative study carried out on students and professors enrolled in different stages of higher education programs in 15 Moroccan universities showed that the educational system faced various challenges, such as a lack of technical support and specific training in the use of newly adopted tools and technologies [1]. This study indicated that end users preferred

traditional over online learning, but also that some teachings must be conducted face-to-face to obtain better results. According to [1], neither professors nor students were satisfied with distance learning. The reasons for their dissatisfaction ranged from technical issues, students' insufficient digital skills, inappropriate content, and materials, to professors' lack of e-learning pedagogical competencies and work overload. It is important to note that face-to-face teaching cannot simply be converted to online teaching, and both approaches have intended learning outcomes as their primary goals.

Student engagement is crucial to achieving e-learning objectives [4]. Certain criteria must be taken into account to enhance student engagement in an e-learning environment [5, 6]. In [5], six factors were identified to improve student engagement, including peer collaboration, interaction with professors, community support, and learning management. In [6], an adaptive e-learning environment was proposed, based on learning styles to reinforce student engagement. In [1], it was found that distance education must be intelligently combined with face-to-face teaching due to the importance of the student-professor relationship, the specificity of the course, and the technological capabilities of the university. Furthermore, the adopted e-learning environment needs specific institutional governance with permanent coordination with the different stakeholders involved.

Based on these findings and considering current competencies, skills and technological issues, Moroccan universities are not yet prepared for e-learning platforms. As a solution, this study proposes an integrated framework for blended learning that considers the specificities of each Moroccan university. This study aimed to answer the following research question: How can an adaptive blended learning framework be implemented and tested to address the challenges faced by Moroccan universities in the transition to online education? The phases involved in this study include qualitative research, literature review, and proposing a generic model, as follows:

- The qualitative research in [1].
- List the terms and explanations through the literature [7].
- Identify the related research model.
- Analyze studies and research to propose a generic model.
- Conduct case studies to test the model.

Blended learning has emerged as a popular approach in education, combining online learning with traditional face-to-face instruction. This approach seeks to leverage the benefits of both modalities, offering flexibility, interactivity, and personalization to learners [8]. The increasing availability of digital technologies and the changing educational landscape have contributed to the adoption and implementation of blended learning in various educational institutions [9]. However, to ensure its effectiveness, efficient scheduling and optimization of learning activities are crucial. This section provides an overview of blended learning, explores the importance of scheduling in educational contexts, and presents the rationale for developing a new framework.

#### A. Scheduling and Optimization in Education

Efficient scheduling of learning activities is essential for educational institutions to effectively utilize resources, meet student needs, and ensure a well-organized learning environment. Traditional scheduling methods, often manual or based on fixed schedules, can be inflexible and may not accommodate the diverse preferences and constraints of students and faculty [10]. Optimization techniques offer a promising approach to address scheduling challenges by leveraging algorithms and computational methods to generate optimal or near-optimal solutions [11]. Scheduling and optimization in education can improve resource allocation, minimize conflicts, and enhance the overall learning experience of students [12]. By utilizing optimization models, educational institutions can efficiently schedule courses, allocate resources, and consider various constraints and preferences of students and faculty members [13]. These models can optimize factors such as class timetables, room assignments, faculty workload, and student preferences, leading to improved efficiency and satisfaction [14]. The integration of scheduling and optimization techniques into educational settings has the potential to enhance the quality of education delivery and support effective blended learning experiences.

#### B. Previous Research and Existing Models

Previous research related to scheduling and blended learning has examined various aspects of these topics. Studies have explored the impact of scheduling on student engagement, satisfaction, and learning outcomes in blended learning environments [15, 16]. Researchers have also investigated the role of technology in supporting flexible scheduling options and providing personalized learning experiences [17]. In terms of existing models and frameworks, several approaches have been proposed to address scheduling challenges in education. These models utilize optimization techniques, algorithms, and artificial intelligence to generate efficient schedules that consider constraints, preferences, and resource allocation [18]. However, previous approaches have strengths and weaknesses. Some models may focus more on specific aspects of scheduling, such as course timetabling or resource allocation, while overlooking other factors [12, 19]. Additionally, certain models may require extensive computational resources or struggle to handle large-scale scheduling problems effectively [20]. Therefore, a comprehensive analysis of previous approaches is essential to identify their limitations and potential areas for improvement in scheduling practices.

#### C. Rationale for this Study

The rationale for this research project lies in identifying the gaps and shortcomings in existing models and frameworks for scheduling and evaluating blended learning in educational contexts. Through a comprehensive analysis of previous approaches, it has been observed that some models may not adequately address certain aspects of scheduling or struggle to handle large-scale problems effectively. Additionally, existing evaluation models may not fully capture the diverse needs and preferences of students and faculty. Therefore, there is a need to develop a new blended learning framework and evaluation model that can address these limitations and enhance the efficiency and effectiveness of scheduling and evaluation

processes. Such a framework has the potential to optimize resource allocation, minimize conflicts, and provide personalized learning experiences for students and faculty members. By bridging identified gaps, this research project aims to contribute to the advancement of scheduling and evaluation practices in education, ultimately leading to improved learning outcomes and a well-organized blended learning environment [21].

#### D. Motivation

The outbreak of COVID-19 has catalyzed a seismic shift in educational settings, requiring institutions worldwide to pivot quickly to online learning modalities. However, this transition has exposed inherent inefficiencies within many e-learning platforms, especially regarding the lack of face-to-face interactions that are crucial to fostering student engagement and facilitating effective pedagogical delivery. The COVID-19 crisis has revealed the inadequacies of conventional e-learning platforms, accentuating the indispensability of interpersonal dynamics inherent in face-to-face interactions between students and professors [22]. Recognizing these deficiencies, this study presents a novel adaptive blended learning framework aimed at enhancing the shortcomings of traditional e-learning approaches in the post-COVID-19 era with the need for an innovative pedagogical framework capable of seamlessly integrating the benefits of both virtual and in-person instruction. Due to this exigency, a pioneering adaptive blended learning framework is needed to address the multifaceted challenges precipitated by the pandemic, combining the power of operational research and advanced technologies, such as artificial intelligence. The main goal of the proposed framework is to optimize learning experiences, fostering enhanced student engagement and academic outcomes. It adopts a holistic approach, considering the requirements of students, professors, and institutional directives, offering a comprehensive solution to the challenges posed by the pandemic-induced educational landscape. It also considers psychological factors to enhance participation after COVID-19, recognizing the importance of addressing the psychological well-being of students and professors, along with institutional requirements, in shaping effective pedagogy.

## II. PROPOSED FRAMEWORK

The proposed framework is based on the blended learning approach, integrating online and offline learning activities and resources to reduce in-class seat time for students in a face-to-face environment, which provides significant advantages for universities. Through blended learning, university management can enhance under-enrolled programs, ensure faculty teaching loads are met, and improve cost-effectiveness. In addition, blended learning offers students a unique and flexible learning experience, allowing them to access their educational program from anywhere and at any time. Participants are not required to physically be present on campus to participate actively in various learning activities [22].

Several frameworks have been proposed in this context. In [23], an ADDIE instructional model was used to design a Blended Project-Based Learning (BPBL) environment with a production approach. This study demonstrated how the ADDIE

instructional model can be systematically employed in the development of a production-based BPBL model, following clear and directed development steps. In [24], a theoretical framework was presented, composed of five factors (blended learning concept, implementation and support, blended pedagogy, ethical considerations, and evaluation and quality of learning), which are considered key factors in formulating a blended learning framework applicable to Saudi universities. The objective was to describe the factors that influence the implementation of blended learning in Saudi Arabian universities. In [25], the evolution of e-learning to blended learning and the use of modern technologies, such as artificial intelligence, and learning models, such as microlearning and distance learning, were explored to enhance blended learning. In [26], an adaptive e-learning system was proposed based on a multi-agent approach. This system aims to recommend a learning path for students that aligns with their characteristics and preferences, utilizing the Q-learning algorithm.

#### A. Framework Architecture and Implementation

Based on the blended learning approach, the architecture of the proposed framework, as illustrated in Figure 1, consists of four interdependent modules that allow for the effective modeling of distance education based on a set of Key Performance Indicators (KPIs) and users' experiences. The ingredients defined in Figure 1 have been integrated into each component, taking into account all the factors discussed for each ingredient. It should be noted that the input and output data will enable the model to adapt the setup according to the context, level, and required culture. To ensure precision, the input data of the framework consist of the following definitions:

- **Course materials:** This includes all course content, support materials, videos, tutorials, and practical work offered. Each course must encompass these elements throughout its duration and sessions.
- **Learning model:** This information defines the type of teaching that will be adopted, whether it is face-to-face, distance, or hybrid. In this context, there may be parallel lessons for the same course, with some students attending face-to-face and others participating remotely.
- **Institutional factors:** This information specifies any constraints or requirements that need to be considered, such as legal aspects or cultural considerations (e.g., gender or age separation).
- **Student profile:** To ensure effective learning and user adoption of the model, a set of criteria can be defined to determine the student's profile. This may include preferences for the teaching model, age, chronotype (e.g., morning or evening person), scientific preferences, etc.
- **Finally,** the professor's profile corresponds to the characteristics and preferences of the instructors. This includes their preference for distance or face-to-face teaching, preferred time slots, preferred semesters, etc.

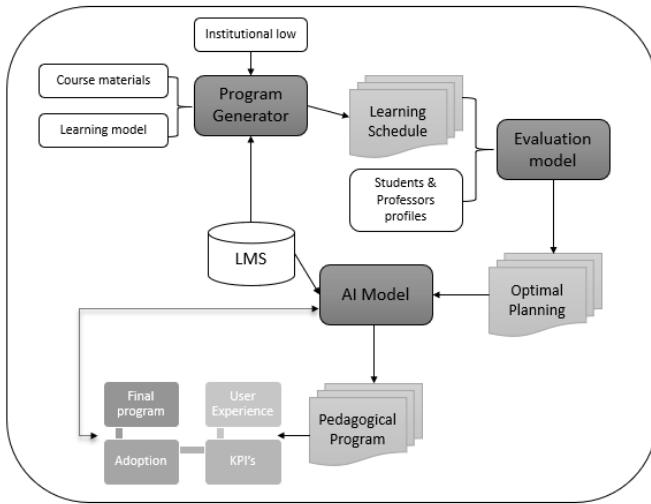


Fig. 1. The architecture of the proposed framework.

According to the concept defined in [27], an effective learning framework solution needs to incorporate a wide range of features to offer a robust system, such as facilitating communication, generating the program, and a system of evaluation of resources that are combined with a Learning Management System (LMS) with benefits that are easily obtainable remotely as well as on-site. This stage of e-learning delivery requires a variety of instructional channels. The proposed framework incorporates different features to organize personalized learning, in addition to the monitoring and reporting of educational entities.

1) LMS Platform

In general, an LMS platform is an integrated set of interactive online services that provide trainers, learners, and others involved in education with information, tools, and resources to support and improve the delivery and management of education [26]. This component is incorporated into the proposed framework to gain access to all resources related to the educational process. The proposed framework should be compatible with all e-learning platforms.

2) Program Generator

The objective of this component is to generate a scheduled program for the courses according to the course syllabus, the learning model, and institutional information. This component should expose all feasible and possible programs that can be applied in the university and will depend on institutional input. This creates a variety of programs that can be generated according to the required learning.

A generated program is a decomposition of lessons into a variable and ordered session set. The proposed breakdown must contain the number of sessions, their types, their order during the course, and their duration. The information depends on the criteria of the institution. For each session, a teaching method can be offered that may or may not be satisfied depending on the constraints of the teacher, the students, and their preferences.

3) Evaluation

This component implements an optimization model that proposes a scheduled program in a time horizon that can be semester, trimester, or annual, according to the students' and professors' profiles. For each student, a scheduled program can be proposed on the time horizon for each session respecting the order, learning mode, and institution criteria. Each optimal planning is a list of the scheduled sessions at a given time, and a learning mode is proposed for each session. Note that if the session is defined onsite, all students will have this session scheduled at specific times. However, if the session can be remote, different time slots can be proposed for each student, according to his preference. Remote sessions can also be conducted onsite for students who do not have the equipment, infrastructure, and learning space to ensure efficient learning. Many works have been presented in this context to suggest a learning model that is flexible and adaptable to the study environment [28]. This component will allow us to efficiently accommodate a range of diverse university requirements, based on criteria that are adjustable to the context (pandemic, summer school, professor profiles, student profiles, etc.).

NOMENCLATURE

$S_i \in S, i \in \{1, \dots, n\}$ : $S$ is a set of students, $i$ is the index of the student, and $n$ is the total number of students. $P_k \in P, k \in \{1, \dots, m\}$ : $P$ is a set of professors, $k$ is the index of the professor, and $m$ is the total number of professors. $C_s \in C, s \in \{1, \dots, l\}$ : $C$ is the set courses, $s$ is the index of the course, and $l$ represents the number of courses. $Se_j \in S, j = \{1, \dots, a_s\}$ : $Se$ is a set of sessions $j$ in the course $C_s$ , $j$ is the index of the session, and $a_s$ is the number of sessions of course $s$ $A_k = \{0, 1, 2\}$ is the professor's academic requirement, {0: onsite, 1: remote, 2: hybrid} $Pr_i = \{0, 1, 2\}$ is the student's preferred learning mode {0: onsite, 1: remote, 2: hybrid} $R_{i,b}$ is a binary variable, $i \in \{1, \dots, n\}, b \in \{1: \text{equipment}, 2: \text{connection}, 3: \text{learning space}\}$ $C_i$ : The final chosen mode for student $i$ considering $A_k, Pr_i$ , and $R_{i,i}$ $H$ : Scheduling horizon $T_{total}$ : Total time for all courses $t_{start}$ : Start time of the scheduling horizon $t_{end}$ : End time of the scheduling horizon $t_{start_s}$ : Start time of course $s$ $t_{end_s}$ : End time of course $s$ $d_{session_j}$ : Duration of a session $j$ $d_{eval}$ : Duration of evaluation $\tau_{start_{s,j}}$ : Start time of session $j$ in course $s$ $\tau_{end_{s,j}}$ : End time of session $j$ in course $s$ $T_s$ : required hours by course / $\{d_{eval}\}$ $t_{eval_k}$ : start time of evaluation session $a_{s+1}$ in course $s$
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

The proposed system consists of three categories of constraints. The first category deals with the student's angle, where each student has a preferred learning mode (hybrid, onsite, or remote) for each course. However, the distant learning mode is conditioned for students to have the correct environment to support its use. Although a student can prefer a remote or hybrid mode, if the subcriteria are not met, he/she is obliged to be onsite to use the university tools. These criteria are as follows: the student needs to have the right equipment, a stable internet connection, and a calm learning space where focus can be achieved.

The second category focuses on the professor's angle. The professor can determine the learning mode for the course based on the academic requirement of the latter. Some courses are better assimilated on-site, for example, if the learning process includes experimentation. Thus, the professor's academic requirement can override the student's preference. Professors can also define the learning mode based on their capacity to adapt to remote mode technology, as is the case with aged senior professors.

The third category of constraints is directly linked to the scheduling problem. In this use case, for a six-month scheduling horizon of equivalently 600 hours, 7 courses of 428 total hours are to be scheduled, all mandatory, meaning that each student must take all of the courses. The order of courses is considered pre-determined for now, but the aim is to integrate course allocation into the scheduling horizon in the future. This will allow us to further analyze the correlations and interdependencies between the courses to determine the most beneficial sequence of knowledge acquisition. Every course is divided into several sessions, which cannot overlap and are

consecutive, and only one session can be scheduled at a given time interval. The courses also cannot overlap. Each session has a specific type {CM, TD, TP, Eval}. The list of both students and the professor, their preferences, and academic requirements are considered inputs.

The following assumptions are considered: (a) for each course, the session has to be scheduled according to an order, (b) the duration must be respected for each session, (c) only one session can be scheduled at a given time interval, (d) if a session is defined as onsite, all the students could be present, (e) only students that have the equipment, learning space, and infrastructure can be on remote.

Objective function: The aim is to maximize the total rest time between the end of sessions  $Se_j$  of a given course  $C_s$  and the evaluation session. Thus tests are defined as the time duration between  $t_{end_s}$  and  $t_{eval_s}$ , as the start time of the evaluation session for course  $s$ .

The following table presents the mathematical formulas and the interpretation of each constraint and objective function.

TABLE I. MATHEMATICAL FORMULAS AND INTERPRETATION FOR OBJECTIVE FUNCTION AND CONSTRAINTS

	Equation	Interpretation
Objective function	$f(t)_{max} = \sum t_{end_s} + t_{eval_s}$	The aim is to maximize the total rest time between the end session $Se_j$ of a given course $C_s$ and the evaluation session. Thus define the time between $t_{end_s}$ (end time of course $s$ ) and $t_{eval_s}$ (start time of evaluation session for course $s$ ).
Constraints		
Constraints for student preferences and environment for distant learning	For each $Pr_i = \{1,2\}, \forall i \in \{1, \dots, n\},$ $\sum_{b=1}^3 R_{i,b} = 3.$ in order to $Pr_i$ to be valid	$R_{i,b}$ binary variable, $i \in \{1, \dots, n\},$ $b \in \{1: \text{equipment}, 2: \text{connection}, 3: \text{learning space}\},$ such as : $R_{i,b} = 1$ if student $i$ has requirement $b, 0$ otherwise. It is important to note that student preference $Pr_i$ and requirements $R_{i,b}$ should be aligned. If $Pr_i = \{1, 2\},$ it is strictly conditioned by student $i$ having all requirements $b$ in place: For each $Pr_i,$ student $i$ needs to have the requirements for his preference taken into consideration.
Constraints for professor academic requirements	$A_k$ overrides $Pr_i$ such as: $\forall i \in \{1, \dots, n\}, \forall k \in \{1, \dots, m\}$ $\sum_{b=1}^3 R_{i,b} = 3$ and $(A_k \neq Pr_i \rightarrow C_i = A_k = Pr_i   A_k \neq Pr_i \rightarrow C_i = A_k)$	It is important to note that between the academic requirement $A_k$ defined by the professor and the preference for learning mode $Pr_i$ defined by the student, priority is given to the professor's decision since it depends more on the nature of the course to be given.
Scheduling constraints and calculations	For each course $C_s \in C, s \in \{1, \dots, l\}$ $H \geq \sum_{s=1}^l T_s + l \cdot d_{eval} \quad (1)$ $t_{end_s} \leq t_{start_{s+1}} \quad (2)$ $\forall i \in \{1, \dots, l\}, \forall j \in \{1, \dots, a_{s+1} + 1\}$ $\tau_{end_{i,s}} \leq \tau_{start_{i,s+1}} \quad (3)$ The start and end time for each course $s$ and session $j$ is calculated as: $\forall s \in \{1, \dots, l\}; a_s = T_s / d_{session_j}$ $\left\{ \begin{array}{l} \text{For } s = 1: t_{start_s} = t_{start} = 0 \\ \text{For } s \geq 2, i \in \{1, \dots, l\}: t_{start_s} = t_{end_{s-1}} = t_{start_{s-1}} + a_s \cdot d_{session_j} + d_{eval} \end{array} \right. \quad (4)$ $\text{For } s = 1, j = 1, \tau_{start_{s,j}} = t_{start} = 0$ $\forall s \geq 2, s \in \{1, \dots, l\}, j = 1:$ $\tau_{start_{s,j}} = t_{end_{s-1}}$ $\forall 2 \geq j \geq a_s:$ $\tau_{start_{s,j}} = \tau_{end_{s,j-1}} + d_{session_j} \quad (5)$ $j = a_s + 1:$ $\tau_{end_{s,j-1}} = \tau_{start_{s,j-1}} + d_{session_j} + t_{rest_s} + d_{eval}$ $t_{eval_s} = \tau_{start_{s,j-1}} + d_{session_j} + t_{rest_s} \quad (6)$	(1) Scheduling horizon constraint (2) Overlapping courses constraint (3) Overlapping sessions constraint (4) Setting courses' time (5) Setting sessions' time (6) Integrating the rest time and setting the debut time for the evaluation session.

#### 4) AI Model

In the future, an AI model will be employed to adapt the accepted model based on the peer learning approach. The idea is to automatically match the learning program with the different requirements of students and professors with respect to their levels, planning, choices, etc. This model can be very useful because it can develop and mimic the human reasoning and decision-making process when designing the learning and teaching framework. In addition, it can manage uncertainty and facilitate the development of a context that supports effective learning and teaching.

### III. RESULTS & DISCUSSIONS

#### A. Results Discussions

The application of the proposed adaptive blended learning framework to an engineering school setting yielded promising results, demonstrating its efficacy in generating optimal planning tailored to individual student and professor preferences. The proposed framework generated a trimester plan, which encompassed a meticulously designed schedule that balanced various modes of instruction (online classes, face-to-face sessions, and evaluation periods) while ensuring ample time for revision and consolidation of learning. The proposed framework reflects a holistic approach to education, integrating diverse instructional modalities while prioritizing flexibility, engagement, and academic rigor. By carefully balancing online and face-to-face interactions, incorporating evaluation periods, and providing ample time for revision, the proposed framework empowers students to navigate their learning journey effectively, maximize their learning outcomes, and thrive in dynamic educational environments.

#### B. Limitations

Limitations in terms of experimentation and implementation should be considered when adopting a blended learning framework. First, conducting experiments to evaluate the effectiveness of blended learning can be challenging, as it requires careful planning, data collection, and analysis to measure the impact on student outcomes, engagement, and satisfaction. Furthermore, conducting controlled experiments with a large sample size may pose logistic and resource constraints. Variability in student learning styles [29], prior knowledge, and motivation also add complexity to experimental design and analysis. Other limitations could also be considering the infrastructure of the Moroccan context. The implementation of such a framework requires Internet connectivity and the student and the professor have the necessary equipment to allow them to easily exploit and use the system.

### IV. CONCLUSION

This study presented an integrated framework that aims to enhance learning efficiency through a blended learning approach. The framework consists of three main components:

- A program generator: An approach to generate a list of sessions and propose a learning mode according to the course priorities and the institution's criteria.

- An evaluation model to propose optimal scheduling for each student based on the generated session, students' and professors' preferences, and institutional policies.
- An AI model to match learning programs with student preferences based on the output of the proposed framework. This study focused on the first two components.

The concept in this proposed framework revolves around ensuring access to learning for all students while considering the unique characteristics of each university. The role of the proposed model is to promote blended learning with a clear breakdown of remote and onsite learning for all stakeholders. This model empowers stakeholders to actively contribute to the advancement of education. This approach emphasizes the importance of balancing individual with collective interests and recognizes the significance of employing diverse teaching methods that cater to the varying pedagogical requirements across different courses and subjects. This model underscores the necessity of adapting the pedagogy to accommodate the capacities and knowledge of students [6]. This fundamental principle should be increasingly embraced within the field, ensuring that the educational needs of all individuals are valued and addressed.

In terms of existing models and frameworks, several approaches have been proposed to address scheduling challenges in education. These models utilize optimization techniques, algorithms, and artificial intelligence to generate efficient schedules that consider constraints, preferences, and resource allocation [10, 18]. However, previous approaches have strengths and weaknesses, with some focusing more on specific aspects of scheduling, such as course timetabling or resource allocation, while overlooking others [12, 19]. Additionally, certain models may require extensive computational resources or struggle to handle large-scale scheduling problems effectively [20].

### REFERENCES

- [1] S. Elfidoussi, M. Lachgar, H. Kabaili, A. Rochdi, D. Goujdami, and L. El Firdoussi, "Assessing Distance Learning in Higher Education during the COVID-19 Pandemic," *Education Research International*, vol. 2020, no. 1, 2020, Art. no. 8890633, <https://doi.org/10.1155/2020/8890633>.
- [2] Y. Chen, A. Y. C. Hou, and L. Huang, "Development of distance education in Chinese higher education in perspectives of accessibility, quality and equity under COVID-19," *Asian Education and Development Studies*, vol. 11, no. 2, pp. 356–365, Feb. 2021, <https://doi.org/10.1108/AEDS-05-2020-0118>.
- [3] V. Navickiene, V. Dagiene, E. Jasute, R. Butkiene, and D. Gudoniene, "Pandemic-Induced Qualitative Changes in the Process of University Studies from the Perspective of University Authorities," *Sustainability*, vol. 13, no. 17, Jan. 2021, Art. no. 9887, <https://doi.org/10.3390/su13179887>.
- [4] L. M. Nkomo, B. K. Daniel, and R. J. Butson, "Synthesis of student engagement with digital technologies: a systematic review of the literature," *International Journal of Educational Technology in Higher Education*, vol. 18, no. 1, Jun. 2021, Art. no. 34, <https://doi.org/10.1186/s41239-021-00270-1>.
- [5] J. Lee, H. D. Song, and A. J. Hong, "Exploring Factors, and Indicators for Measuring Students' Sustainable Engagement in e-Learning," *Sustainability*, vol. 11, no. 4, Jan. 2019, Art. no. 985, <https://doi.org/10.3390/su11040985>.
- [6] H. A. El-Sabagh, "Adaptive e-learning environment based on learning styles and its impact on development students' engagement,"

- International Journal of Educational Technology in Higher Education*, vol. 18, no. 1, Oct. 2021, Art. no. 53, <https://doi.org/10.1186/s41239-021-00289-4>.
- [7] S. Elfirdoussi, M. Lachgar, and H. Kabaili, "Modèle conceptuel de l'enseignement à distance : une revue de littérature," in *MENACIS 2021*, 2021.
- [8] D. R. Garrison and H. Kanuka, "Blended learning: Uncovering its transformative potential in higher education," *The Internet and Higher Education*, vol. 7, no. 2, pp. 95–105, Apr. 2004, <https://doi.org/10.1016/j.iheduc.2004.02.001>.
- [9] Y. Akpınar, "Liberating learning object design from the learning style of student instructional designers," *Performance Improvement*, vol. 46, no. 10, pp. 32–39, 2007, <https://doi.org/10.1002/pfi.169>.
- [10] R. A. O. Vrielink, E. A. Jansen, E. W. Hans, and J. van Hillegersberg, "Practices in timetabling in higher education institutions: a systematic review," *Annals of Operations Research*, vol. 275, no. 1, pp. 145–160, Apr. 2019, <https://doi.org/10.1007/s10479-017-2688-8>.
- [11] E. K. Burke, P. De Causmaecker, G. V. Berghe, and H. Van Landeghem, "The State of the Art of Nurse Rostering," *Journal of Scheduling*, vol. 7, no. 6, pp. 441–499, Nov. 2004, <https://doi.org/10.1023/B:JOSH.0000046076.75950.0b>.
- [12] H. Babaei, J. Karimpour, and A. Hadidi, "A survey of approaches for university course timetabling problem," *Computers & Industrial Engineering*, vol. 86, pp. 43–59, Aug. 2015, <https://doi.org/10.1016/j.cie.2014.11.010>.
- [13] S. Ceschia, L. Di Gaspero, and A. Schaerf, "Educational timetabling: Problems, benchmarks, and state-of-the-art results," *European Journal of Operational Research*, vol. 308, no. 1, pp. 1–18, Jul. 2023, <https://doi.org/10.1016/j.ejor.2022.07.011>.
- [14] M. Kaviani, H. Shirouyehzad, S. M. Sajadi, and M. Salehi, "A heuristic algorithm for the university course timetabling problems by considering measure index: a case study," *International Journal of Services and Operations Management*, vol. 18, no. 1, pp. 1–20, Jan. 2014, <https://doi.org/10.1504/IJSOM.2014.060448>.
- [15] J. Schmidt, "Blended learning in K-12 mathematics and science instruction – An exploratory study," Ph.D. dissertation, University of Nebraska at Omaha, 2013.
- [16] H. Hasanah and M. N. Malik, "Blended Learning in Improving Students' Critical Thinking and Communication Skills at University," *Cypriot Journal of Educational Sciences*, vol. 15, no. 5, pp. 1295–1306, 2020.
- [17] C. Cocquyt, C. Zhu, A. N. Diep, M. De Greef, and T. Vanwing, "Examining the role of learning support in blended learning for adults' social inclusion and social capital," *Computers & Education*, vol. 142, Dec. 2019, Art. no. 103610, <https://doi.org/10.1016/j.compedu.2019.103610>.
- [18] R. Bellio, S. Ceschia, L. Di Gaspero, A. Schaerf, and T. Urli, "Feature-based tuning of simulated annealing applied to the curriculum-based course timetabling problem," *Computers & Operations Research*, vol. 65, pp. 83–92, Jan. 2016, <https://doi.org/10.1016/j.cor.2015.07.002>.
- [19] N. Pillay, "A survey of school timetabling research," *Annals of Operations Research*, vol. 218, no. 1, pp. 261–293, Jul. 2014, <https://doi.org/10.1007/s10479-013-1321-8>.
- [20] E. Tuncel, A. Zeid, and S. Kamarthi, "Solving large scale disassembly line balancing problem with uncertainty using reinforcement learning," *Journal of Intelligent Manufacturing*, vol. 25, no. 4, pp. 647–659, Aug. 2014, <https://doi.org/10.1007/s10845-012-0711-0>.
- [21] K. Verbert, E. Duval, J. Klerkx, S. Govaerts, and J. L. Santos, "Learning Analytics Dashboard Applications," *American Behavioral Scientist*, vol. 57, no. 10, pp. 1500–1509, Oct. 2013, <https://doi.org/10.1177/0002764213479363>.
- [22] P. Shayan and E. Iscioglu, "An Assessment of Students' Satisfaction Level from Learning Management Systems: Case Study of Payamnoor and Farhangian Universities," *Engineering, Technology & Applied Science Research*, vol. 7, no. 4, pp. 1874–1878, Aug. 2017, <https://doi.org/10.48084/etasr.1041>.
- [23] F. Han and R. A. Ellis, "Patterns of student collaborative learning in blended course designs based on their learning orientations: a student approaches to learning perspective," *International Journal of Educational Technology in Higher Education*, vol. 18, no. 1, Dec. 2021, Art. no. 66, <https://doi.org/10.1186/s41239-021-00303-9>.
- [24] M. Adri, T. S. Wagiyumi, Ganefri, S. Zakir, and J. Jama, "Using ADDIE instructional model to design blended project-based learning based on production approach," *International Journal of Advanced Science and Technology*, vol. 29, no. 06, pp. 1899–1909, 2020.
- [25] R. Alebaikan, "A blended learning framework for Saudi higher education," presented at the Second International Conference of E-Learning and Distance Learning, Riyadh, Saudi Arabia: National Center for E-Learning and Distance Learning, 2011.
- [26] H. E. Fazazi, M. Elgarej, M. Qbadou, and K. Mansouri, "Design of an Adaptive e-Learning System based on Multi-Agent Approach and Reinforcement Learning," *Engineering, Technology & Applied Science Research*, vol. 11, no. 1, pp. 6637–6644, Feb. 2021, <https://doi.org/10.48084/etasr.3905>.
- [27] H. Singh, "Building Effective Blended Learning Programs," in *Challenges and Opportunities for the Global Implementation of E-Learning Frameworks*, IGI Global Scientific Publishing, 2021, pp. 15–23.
- [28] N. Sawhney, "E-learning: Global education without walls," *Educational Quest-An International Journal of Education and Applied Social Sciences*, vol. 3, no. 1, pp. 35–41, 2012.
- [29] E. Barbierato, L. Campanile, M. Gribaudo, M. Iacono, M. Mastroianni, and S. Nacchia, "Performance evaluation for the design of a hybrid cloud based distance synchronous and asynchronous learning architecture," *Simulation Modelling Practice and Theory*, vol. 109, May 2021, Art. no. 102303, <https://doi.org/10.1016/j.simpat.2021.102303>.