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Original Article

Adaptive Personalized Learning Systems: Enhancing Innovation and Entrepreneurship in Software Engineering Education

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Abstract - *Innovation and entrepreneurship are critical skills for university students in today's fast-paced global economy. However, traditional educational models frequently fail to accommodate the diverse learning needs and aspirations of students, particularly in innovation-related fields such as programming, web design, and databases. This study presents a personalized learning system designed to enhance student engagement and foster entrepreneurial skills. The system utilizes academic performance data to generate tailored course recommendations, categorizing students by proficiency and aligning learning paths with their educational history, competencies, and career aspirations. The system was tested with 200 students from the Software Engineering Department at Al-Zaytoonah University of Jordan, using academic records, system interaction logs, and student surveys to collect data. The methods used for data analysis include both quantitative and qualitative approaches. Pre- and post-test performance scores were analyzed using statistical tests, such as t-tests, and descriptive statistics. Survey responses were analyzed using qualitative coding techniques. Results showed a 35% increase in student engagement and a 20% increase in academic performance. Further, 78% of students indicated increased readiness to work on innovative projects. This study makes a significant contribution to the literature on personalized learning and supports students' preparation for careers in rapidly evolving, innovation-driven industries.*

Keywords - *Adaptive Educational Technology, AI in Education, Data-driven learning, Entrepreneurship Education.*

1. Introduction

Innovation and entrepreneurship have become increasingly significant in higher education, particularly as students transition from academic environments into entrepreneurial ventures and dynamic career paths [1]. Within the context of a rapidly evolving global economy, universities are expected not only to deliver high-quality academic instruction but also to foster essential competencies such as critical thinking, creativity, and problem-solving. To thrive in an era where adaptability and innovation are key drivers of economic progress, students must develop these foundational skills. As technology continues to develop, and in turn is affecting changes to existing industries and creating new industries, areas of expertise, including programming, web development, and database management, have taken on a significant role in shaping innovation and entrepreneurial practices in modern technical fields. Luckily, students who develop expertise in these areas are in a better position to produce meaningful contributions toward technology and business innovations, which remain important foundations for being entrepreneurial [2]. While entrepreneurial and technical competencies are continuing to grow in significance, students still often have difficulties recognizing their own strengths and weaknesses [3]. Traditional education is not typically structured to assist people in identifying specific strengths or weaknesses or recognizing issues that people may face. The problems are further exacerbated by other factors, such as technology and the variety of conditioned skills individuals take on through agreed-upon social processes. Some students encounter challenges with entrepreneurship education due to the limited feedback on and knowledge of their needs [4]. When learning technical domains such as programming or web design, the issues may be intensified as learning is cumulative based on prior knowledge. There is a discrepancy in learning that can limit student apprehension of some of the significant ideas and hinder the student from feeling competent and getting a sense of progress [5]. While there is increasing use of adaptive and AI-supported learning tools by educators, very few of these tools are designed to support academic performance analytics within the context of entrepreneurship-oriented learning pathway development. In general, most current models provide improvements to

performance in a specific course or provide generic recommendations for students without regard to their overall strengths/weaknesses and innovation capabilities. There is also limited empirical research to show how personalized learning platforms can be strategically integrated into technical programs at universities and how these platforms will affect students' ability to pursue entrepreneurship in actual classroom environments. These gaps clearly identify the need for an integrated framework that utilizes student performance data to create and support individualized learning pathways while simultaneously creating opportunities for entrepreneurial thinking.

This research established an internet-based, personalized learning system in order to create opportunities for students to develop their creative thinking and entrepreneurial abilities as a response to the aforementioned challenges. The proposed system will collect data about each student's entire experience with school learning (academic performance), such as the time taken to complete tasks, and overall grades given at completion of each task. It gives them a customized course based on the modules where they have done the best. Three main areas of technology are involved in the system: programming, web design, and databases, which represent an important part of what entrepreneurs use to grow their business with technology [6]. The personalized aspects of the system are based on already existing models for personalized learning, but also include many dynamic aspects based on the academic background of the student.

The goal of this study is to develop a group of technical skills for the graduating students, along with the creative and critical thinking skills required for an entrepreneurial environment that is constantly evolving [7]. Customized paths to learning, as have been found by recent research in these areas, are common forms of pedagogical strategy that aid in skill development, promote active involvement, support independence through meaningful learning, and allow the students to resolve real-world community problems [8]. The personalized learning pathway supports students who participate in the areas of Innovation & Entrepreneurship by identifying the opportunity gaps and highest growth potential, allowing the student to express their learning strengths and interests in order to unleash the creative and innovative aspects needed to successfully start an entrepreneurial venture [9].

What makes this research study unique is its concentration on developing an educational environment designed for students with their own specific academic capabilities. The majority of the public education systems use standardized curricula and established performance expectations; however, in this project, a Personalized Learning System (PLS) that tracks almost all aspects of a student's previous academic behaviour was designed. It then offers courses that are the most relevant, that fill the gaps in formation, and that enhance innovation. The goal must be not only so that they learn better, but that they come up with ways of thinking about things more innovatively and develop an entrepreneurial spirit that is appropriate for this time [10]. This study contributes to the field of personal education because it indicates how personal education systems can help induce innovation and entrepreneurship in higher education.

Accordingly, the objective of this project is to develop a customized educational program with an adaptive learning model that will make recommendations based upon students' academic performance, and their academic strengths and weaknesses within three areas: Programming, Web Design, and Database. This project will also analyze the impact that a customized educational program has on the students' involvement, academic achievement, and perceived ability to innovate and participate in entrepreneurial activities. This research will address essential inquiry questions regarding the degree to which customized educational programs improve performance in required technical classes, how they increase innovation skills and entrepreneurial confidence among students, and how customized programs may be integrated into the current curriculum of universities to provide both sustainable and scalable models for teaching entrepreneurship education.

2. Literature Review

2.1. Innovation and Entrepreneurship in Higher Education

Innovation and Entrepreneurship are one of the major focuses for many Universities today. There is a growing body of literature supporting the necessity for students to have entrepreneurial skills and knowledge at an early stage of their academic career [11]. Therefore, it is becoming commonplace for universities across the world to focus on providing students with the necessary tools to develop the basic entrepreneurial skills and to provide them with the creativity and problem-solving abilities to take on new business ventures [12].

However, conventional educational procedures still struggle to cope with the growing developmental and learning needs of the pupils pursuing unpredictable and dynamic career pathways. In particular, this predicament afflicts subjects of a technical nature that demand original and creative qualities [13]. An effective way to bridge this proverbial gap could be the use of a personalized learning approach, administering a curriculum personalized according to students' satisfaction and needs while improving general learning efficacy and interest [14].

2.2. The Role of Personalized Learning

Rather than implementing a one-size-fits-all program to meet the needs of a generic or rather typical student, personalized learning supplies individualized personalized learning pathways in which a student progresses along a learning pathway that reflects his or her own unique learning. Each student, optimally, learns at his or her own pace and thus

paves his or her own pathway through a menu of alternatives made available through personalized learning. Shorter cycles of meaningful feedback relevant to the needs of the learner have resulted in student engagement and improved performance and satisfaction with personalized learning systems in the modern arena [15].

When students can focus their efforts on the areas that need the most improvement, personal learning systems result in far more noticeable increases in their skill levels [16]. The base of entrepreneurship includes creating a personal brand that represents the individual's technical skills, knowledge, and ability to address complex problems [17].

The evidence is continuing to build regarding how personalized learning pathways are associated with innovation. For example, a study conducted by [18], demonstrating personalized learning systems and their correlation with student creativity and innovation, found a strong positive statistical correlation. There are studies [19] as well that demonstrated how personalized learning systems also seemed to provide positive contributions to student creators in programming and web design. Personalized learning environments provide opportunities to unlock greater capacity for recognizing challenges and inventing solutions. Personalized recommendations of course topics based on students' interests allowed students to focus on other topics of interest and produce positive studies on academic achievement, and may lead to even more entrepreneurial growth, especially in technical areas [20].

While adaptive learning systems are becoming increasingly prevalent in higher education, many of today's methods are limited in scope and impact. Most current systems optimize content sequence or improve student performance in one course at a time while failing to use the student's total cumulative academic record or identify cross-disciplinary patterns of strength and weakness. In addition, many adaptive learning platforms fail to develop skills for innovation/entrepreneurship development and do not relate learning progress in technical areas to larger skill development. Most models have no long-term mechanism for building profiles of learners, and their recommendations are generally broad and not based on the student's career goals or innovation potential. The personalized learning system described here moves past these limitations by using multi-semester academic records to analyze student performance across programming, web design, and databases, and then providing student-specific learning paths that directly support innovation-based skill development. This comprehensive approach not only fills an important gap in the literature but also presents a more complete model for preparing students for entrepreneurial learning environments.

2.3. Comparison with Existing Adaptive Learning Systems

The proposed system is distinct from other existing adaptive learning models because it ties together personalized learning pathways for students with explicit innovation and entrepreneurial development. Although many adaptive learning systems are focused on delivering content, algorithms for sequencing, and/or predicting performance, relatively few incorporate multi-course performance analytics into pathways directed at developing skills for being an entrepreneur.

Typically, prior systems have been limited to operating within a specific subject area and linking student performance patterns to a larger body of competencies or innovation readiness. The proposed system extends these prior systems as it integrates academic data across three areas of study (programming, web design, and databases) and uses this academic data to provide targeted recommendations to foster creativity, problem-solving, and entrepreneurial initiative. In addition to providing a unique approach to integrating academic data to personalize learning in technical education, the proposed system also provides a unique approach to tying together multiple academic subjects.

Table 1 shows a comparison of the main features of the proposed personalization model to the other adaptive learning models that have been developed previously, as well as an identification of the original contributions to be made by this research with regard to the new personalization model.

Table 1. Comparison between existing adaptive learning systems and the proposed system

Feature	Typical Adaptive Learning Systems	Proposed Personalized Learning System
Scope of Data Used	Usually single-course data; limited historical information	Multi-course academic history across programming, web design, and databases
Focus of Personalization	Content sequencing, difficulty adjustment	Learning pathways + innovation/entrepreneurship skill development
Cross-disciplinary Integration	Rarely integrated; mostly course-specific	Fully integrated across three technical domains
Use of Performance Analytics	Basic performance metrics (e.g., quiz scores)	Strength/weakness analysis, trend evaluation, pathway-aligned recommendations
Entrepreneurship Focus	Almost none	Aligned with innovation and entrepreneurship
Career/Goal Alignment	Generally absent	Focused on innovation and essential future skills

Type of Recommendations	Generic content modules	Tailored courses mapped to academic gaps and innovation readiness
Intended Outcome	Academic improvement in isolated topics	Academic growth + innovation readiness + entrepreneurial mindset

2.4. Applications in Technical Education

Additionally, personalized learning systems will enhance the learning experience. The authors of [21] reported on a genetically-based personalized e-learning system and examined the capability of the system to produce an adaptive learning sequence that considered the learner's abilities, while maintaining a continuity of learning concepts. The results showed significant improvement in learning performance over both the unrestricted and browse-free content delivery. Personalized sequencing mechanisms can reduce cognitive load and provide sequential and logical progression across subjects.

While [22] used deep learning for course recommendations, their study focused primarily on elective selection, not entrepreneurial skill development. This work extends this by directly linking personalization with entrepreneurship readiness, thereby addressing a gap in the literature on how adaptive learning can foster innovation-oriented competencies. In addition, data suggested that students engaging in a recommendation system helped to clarify what the students' classes allowed. Overall, students generally found that the recommendation system had impacted their educational outcomes, becoming just another technological step to engage with their learning and learning experiences. As a result, a personalized learning system could easily be one of the cornerstones for the next generation of innovators and entrepreneurs.

Additionally, research by [23] discusses the development of self-referential digital platforms utilizing artificial intelligence in support of continuous education and learning (professional learning), which directly relates to the integration of personalized learning systems in higher education. The possible digital platforms could achieve education results by offering individual learning pathways.

Moreover, the authors of [24] also studied Artificial Intelligence (AI) in personalized learning systems for e-learning. The authors demonstrated how AI-based learning systems could be used to enhance the learning experience and provide additional innovation and entrepreneurship support in Higher Education with the use of additional AI-based learning environment personalization.

There has been an abundance of research highlighting the positive effects of using personalized learning approaches however there are still many challenges associated with personalized learning systems which have a direct correlation to the level of accuracy of the student data being used by these systems; it should be noted that in order for a personalized learning system to provide students with accurate and reliable suggestions and recommendations the overall system must have accurate and reliable data about each individual student [25]. Another challenge with scalability is that a system that supports personalized learning can be very successful in a smaller group of students. However, at this time, there are still many questions as to whether or not these systems will be able to support larger populations of students [26].

Still, Personalized Learning Systems have the opportunity to create new, innovative, and entrepreneurial practices in Higher Education, and Research will continue to develop and enhance the systems of personalized learning in order to better personalize [27].

Technology in higher education offers substantial promise while also posing considerable challenges. Learning Management Systems (LMS) can be a great tool that can provide personalized learning experiences for students using algorithms that suggest courses that better align with a student's profile [28].

LMS also requires large amounts of money for hardware, training on the LMS, and maintenance. Furthermore, LMS cannot be effective without the successful integration into existing curriculum and instructional practices. The greatest enhancements offered by the tools of personalized learning need to fit within and enhance more traditional curriculum and instructional practice. All students need and deserve educational opportunities that prepare them for academic success and entrepreneurialism [29].

The overall framework of the personalized learning ecosystem is demonstrated in Figure 1, which shows how the technology, data analytics, and course recommendation systems came together to promote innovation and entrepreneurship. The framework demonstrates how a personal learning system could interface with the traditional face-to-face learning curriculum of university educational studies, which augments innovative thinking.

Due to the continual acceleration of technology, specifically in relation to programming, web design, and databases, students have to appreciate the value of ongoing professional development related to their skills. Personalized learning provides a good opportunity for systematically ensuring students actually develop the skills needed to be relevant and current when they enter society, and are successful in their understanding of their skills and ability to survive as they enter careers in technology. Personalized learning pathways contribute not only to student academic

achievement but also prepare students for the incredible speed and often permanent changes enabled by technology. Learner pathway development, especially when it is tailored to individual learners, can be an important factor in developing innovation and entrepreneurial approaches to teaching and learning within higher education. The idea behind creating personalized pathways is to welcome each learner with an open mind; this allows for each learner to develop their own ideas and methods to apply to the material in their courses in a manner that reflects their uniqueness. If developed correctly, this model has the potential to improve learning experiences in post-secondary education and will allow students to gain an actual, realistic educational experience, which is supportive of developing skills and entrepreneurial thinking, both of which have been valued by economies for some time. The numerous practice opportunities present many new questions; e.g., issues around managing and collecting data, if the pathway can be scaled appropriately, and how to develop systems and processes that will create the best possible experience while also being in line with current practices of personalized learning and existing practices. Future research and testing, including addressing these questions, will be a key determinant of whether personalized learning will be best placed to reach the full extent of its potential and have a meaningful effect on feeding the future of innovators and entrepreneurs.

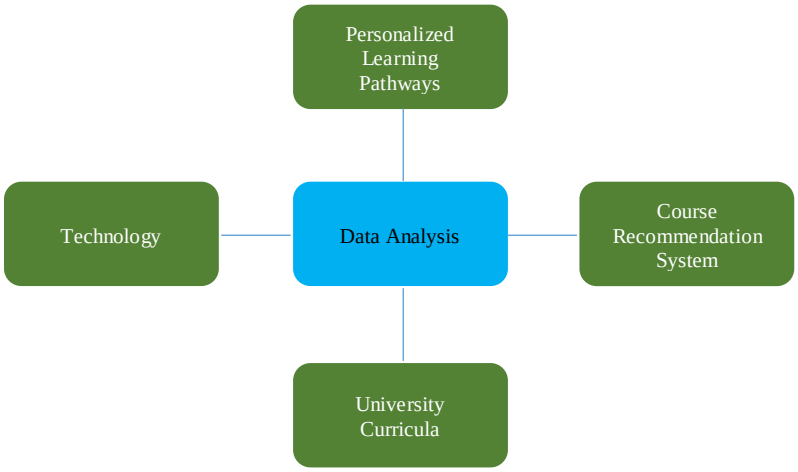

Fig. 1 Personalized learning framework linking academic data with the recommendation engine and learning pathways

3. Methodology

3.1. Personalized Learning System Design

A personalized learning system was developed on the university campus to enhance innovation and entrepreneurship activities. This development took an intertwined approach, integrating both teaching and research with the important aim of appropriately valuing each. The web-based application is presently in the test phase, but is still being modified and developed. The system was tested on a data set containing 200 students from Al-Zaytoonah University of Jordan's Software Engineering Department. Following participant consent in an informed manner, the study proceeded as described above; the study data collection comprised gathering students' academic records, their use of the system reports, and their responses on a survey regarding their views of the learning environment in order to create the data set used in this research. Prior to collecting the data, ethical approval was provided by Al-Zaytoonah University of Jordan. All data collected in this study were subject to the same university ethical standards, and all data collected were treated confidentially. Also, participation in the study was voluntary for all students. To better understand students' programming knowledge, create web designs, and database systems by using academic data, this system will help each student get personalized course recommendations based on their strengths and weaknesses. This system has a systematic student-focused methodology. The purpose of this system is to utilize academic achievement as a means to encourage students along paths of learning to develop essential entrepreneurial and innovative skills.

The development of the personalized learning system proceeded in a collaborative and iterative fashion through four major phases: requirements analysis, prototyping, implementation, and refinement. In the requirements analysis phase, functional and non-functional requirements were gathered from the existing curriculum structure, departmental policies, and input from programming, web design, and database faculty members who would be responsible for the content. During the prototyping phase, a web-based prototype was created to provide the users with an example of the key features, such as registration, importing academic information, and providing suggested learning paths. In the implementation phase, the web-based prototype was integrated into the University's student records, the database schema for storing academic history and log entries of recommendations was defined and implemented, and the recommendation algorithm based on pre-defined rules and performance thresholds was also established. Finally, in the refinement phase, the system received feedback from a small

sample of both students and instructors regarding interface usability, clarity of the recommended pathway, and relevance to the course outcomes to further refine the system. This multi-stage development approach provided the assurance that the system was technically viable while ensuring it remained consistent with its intended pedagogical goals and institutional limitations.

All of the students' data was placed in a protected server that had a password. Only the research team had access to it, and the names and other identifiable information about each of them were stripped from the data before any type of analysis occurred. Participation by students in this study was completely voluntary; they could drop out at any point, and their data would be deleted and therefore be removed from consideration in this study. This process assured all of the students' right to privacy and the security of their data and how it was stored.

3.2. System Architecture and Design

Three main aspects comprise the overall design of the Web Application: Data Extraction, Learning Pathways Based on Students' Preferences, and Course Recommendations. The Web Application allows students to register for use of the tool, and once registered, the tool will allow them to retrieve academic data from either their college's database or from some other system that has been designated by their college as an acceptable source for this type of data. Once the data is extracted for example, courses taken, grades received), the tool generates a student-specific learning pathway, which provides the foundation for generating individualized learning pathways for the students.

The three disciplines of the pathway system include coding, web design, and databases. Each discipline is further broken down into sub-disciplines representing the competencies required for each discipline. The sub-disciplines within each discipline align with the academic curriculum, ranging from introductory courses to advanced courses.

All courses in each sub-discipline have been categorized as either science and technology innovation or enterprise intelligence. By learning the science and technology behind their studies and being able to think entrepreneurially, students can create innovative applications for everything they have learned in a business context.

Figure 2 is an architectural illustration of the system, as it shows how the system retrieves data for students' educational guidance, and relates it to various fields of study and learning materials so that students can follow a learning path based on their individual academic profiles and career goals.

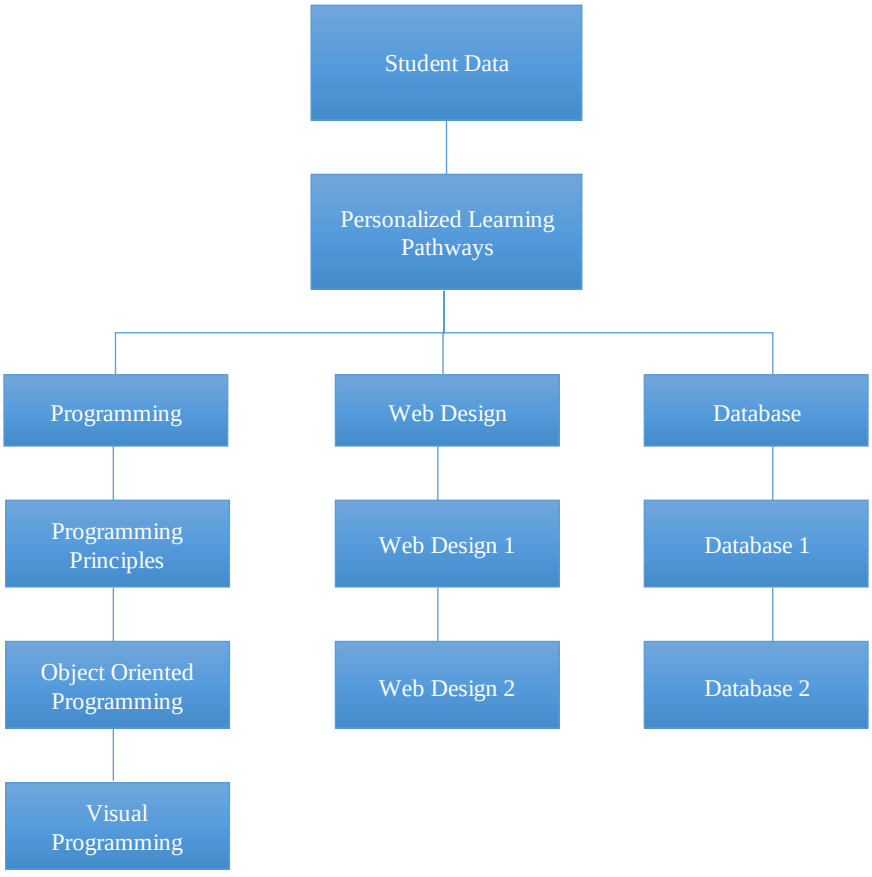

Fig. 2 System architecture illustrating data extraction, pathway generation, and recommendation flow

3.3. Data Analysis and Course Recommendations

The primary purpose of this system is to evaluate student learning and make recommendations regarding which courses would be most beneficial to students, in relation to their strengths and weaknesses. Once the system has received access to the relevant data of the students, it will determine the scores that reflect the proficiency level of each student with respect to each course by evaluating student performance and student completion status. The information obtained from this analysis can help identify gaps in student learning that may benefit from remediation, and/or where additional development is necessary.

Quantitative information was analyzed with both descriptive statistics and a comparison between the performance, engagement, and entrepreneurial readiness in the pre- and post-test using paired-samples t-tests. No significant normality violations were noted. In addition to calculating effect size (Cohen's d), as well as confidence intervals for assessing the practical or real-world importance of the identified changes. Both quantitative and qualitative analyses were completed, pre- and post-test performance scores on descriptive statistics (means and standard deviations) and inferential test interpretations (t-tests) were investigated to determine whether there were statistically significant differences in pre- and post-test performance.

Survey results were coded qualitatively to determine whether the students perceived an increase in their innovation and entrepreneurial capacity. Data were obtained by the mixed-methods approach for a more holistic evaluation of the effects of the system on students' academic performance and innovation efficacy. Student comments about their experience working with the Personalized Learning System (qualitative), which gave additional information about how the system influenced the way students viewed innovation and entrepreneurial readiness, were reviewed along with the quantitative data from the study. A thematic coding technique utilizing an inductive approach was used to analyze the qualitative component of the study, specifically the open-ended portion of the survey.

Two reviewers independently reviewed each of the open-ended responses to the survey; identified recurring themes as they were observed throughout the review process; and discussed any disagreement between them until a consensus was reached. The most frequent themes identified were: an increase in confidence in their technical skills; increased clarity as to their personal strengths and weaknesses; and an increased desire to create innovative projects.

In terms of the type of questions asked in the survey, some of the questions used Likert-type scales, while others were open-ended, such as "How much has the system increased your confidence in programming, web design, or database skills?" and "Did the recommended learning pathway increase your interest in innovation or entrepreneurship? If yes, why?" These qualitative results provided support for the quantitative results and added richness to the results. Recommendations for course selections are made by the system based on the data analyzed in order to support students' weaknesses while maximizing their strengths. For example, if a student passed "Programming Principles" but did poorly, they could be directed to take an introductory-level programming course or a foundational-level course. Similarly, students who may excel in certain areas may be recommended for more advanced classes to push their limits and develop further in fields that are essential in innovation and entrepreneurship.

Table 2. Course details, prerequisites, relevance, and level

Field	Course	Prerequisite	Relevance to Innovation/Entrepreneurship	Level
Programming	Programming Principles	None	Foundational skills in coding	Beginner
	Object-Oriented Programming	Programming Principles	Advanced programming skills for software development	Intermediate
	Visual Programming	Object-Oriented Programming	Visual design tools for application development	Advanced
Web Design	Web Design 1	None	Basic web development skills for entrepreneurs	Beginner
	Web Design 2	Web Design 1	Advanced web design skills for professional web developers	Intermediate
	Smartphone Programming	Web Design 2	Skills in mobile app development for entrepreneurship	Advanced
Database	Databases 1	None	Foundational knowledge in database management	Beginner
	Databases 2	Databases 1	Advanced knowledge in managing complex databases	Advanced

Table 2 provides a comprehensive summary of the courses organized by primary fields (Programming, Web Design, and Databases), their prerequisites, and their use to achieve innovation and entrepreneurship.

A comparison of these courses shows how the system coordinates the educational path and allows the students to take a more specific course while learning critical skills in their area.

3.4. Personalization Algorithm

The learning pathways are largely dependent on the system's personalization algorithm. It analyzes several significant factors, including students' course completion history, grade distribution, and personal student goals (if given).

The algorithm is applied to each student to give each student a performance score in the fundamental areas of programming, web design, and databases. These scores are used for prioritizing the recommended courses so that the student is receiving suggestions in line with their current knowledge and future learning path. The algorithm operates through the steps shown in Figure 3. The web application was designed with an intuitive and user-friendly interface. There is a dashboard for students when they log in that gives them an overview of how well they are doing, like what courses they have completed, what grades they have, and where they need to improve. Additionally, students can rate their course.

Through this interface, students can navigate the system, select interest areas (innovation, programming, or web design), and create their personalized learning pathway. They can also receive alerts when new practice courses or tutorials are available based on where they are, recommendations, and refining the algorithm using machine learning. Figure 4 shows the User Interface for the web application, which consists of the main dashboard that the students would be using. It emphasizes certain features, such as the display of the student's academic track and personalized learning pathways available to the student. The interface of the system is designed in such a way that it is easy and user-friendly, ensuring that the students have easy access to the required information and tools, and at the same time, it is easy to use.

```
Input:
  student data
  course_catalog
Output:

1. Initialize personalized course recommendations as an empty list
2. For each course in student data:
    a. Retrieve completed courses and grades
    b. For each course, evaluate the student's proficiency based on grade and
completion status:
       If grade >= B, assign "Advanced" proficiency
       ii. If grade >= C, assign "Intermediate" proficiency
       iii. If grade < C, assign "Beginner" proficiency
3.     each course in Begine cataloy:
    a. Compare course prerequisites with the student's completed courses
    b. If the student has completed all prerequisites, consider the course for

    c. If the student's proficiency in prerequisite courses is "Intermediate" or
above, prioritize the course
4. Identify areas where the student has "Beginner" proficiency:
    a. For each area, recommend the next logical course that enhances skills in tha
field (e.g., foundational courses or remedial courses)
6. Filter courses that match the student's expressed interests (innovation,
and course level)
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Fig. 3 Personalization algorithm showing the steps used to evaluate performance and generate course recommendations

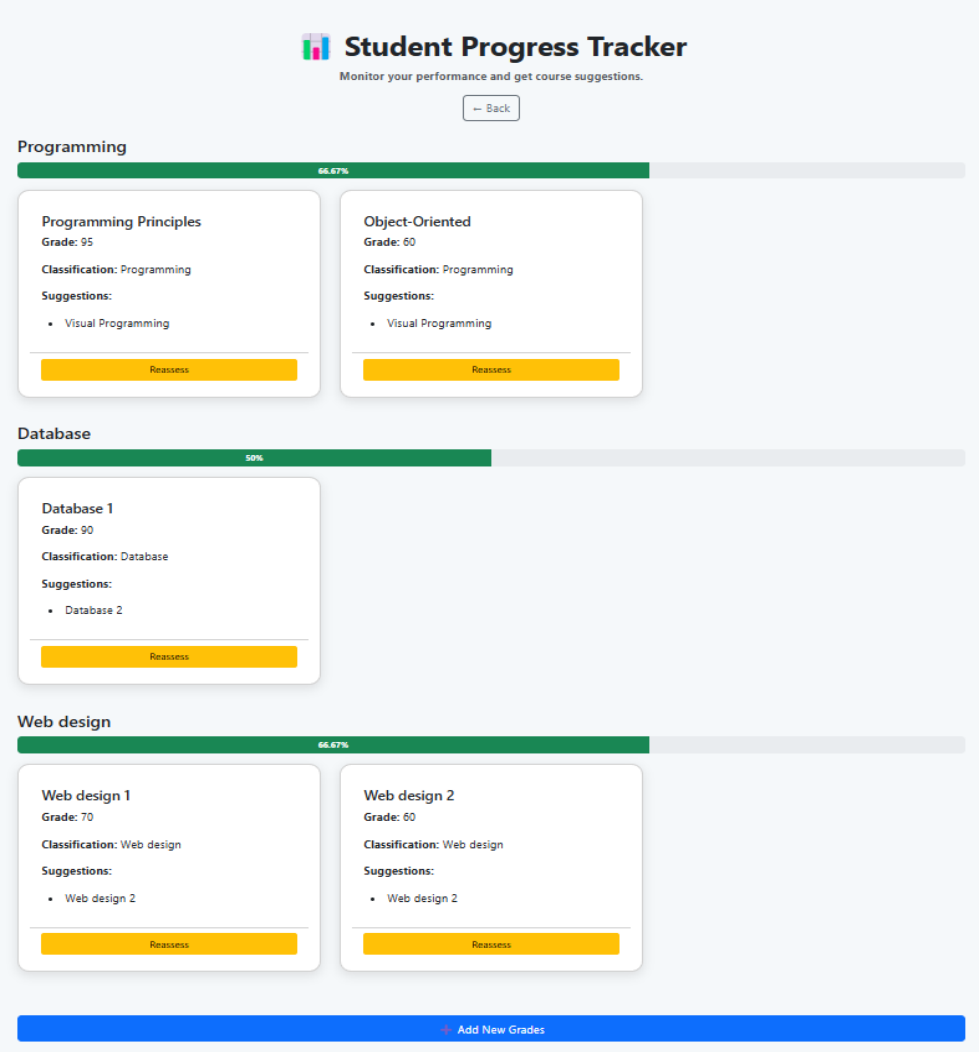

Fig. 4 Student dashboard interface displaying progress tracking and personalized learning pathways

3.5. Experiment Results

This research fills the gap to provide a deeper level of analysis of the results of this research by expanding the Results section with numerous additional quantitative and qualitative analyses supported by more data summaries and displays, including more clearly defining students' achievement in the three areas of study (programming, web design, and databases), reporting effect sizes for all the statistical tests that were conducted, and providing a more detailed discussion of the measures of students' engagement.

The analysis also incorporates qualitative themes extracted from student survey responses to provide a more richly contextualized understanding of how the students' use of Personalized Learning Pathways impacted their Innovation Readiness. The addition of these analyses ensures that the current study is a more complete and rigorous examination than would be expected by scholars conducting Advanced Scholarly Research. The empirical results of the user testing of the personalized learning system with 200 students from the Software Engineering Department are described in this section. In order to assess how effective the system was, some testing was done to demonstrate whether the system influenced student engagement, learning outcomes, and entrepreneurial-oriented thinking.

After analysing whether the outcomes were statistically significant and showed substantive changes in all three dimensions of student thinking, there is solid evidence that custom pathways can enhance students' technical skills and entrepreneurial capabilities.

3.6. Testing Methodology and Data Collection

The system was evaluated on 200 students from the Software Engineering Department at Al-Zaytoonah University. The sample was composed of freshmen, sophomores, and juniors. The evaluation began by prompting each individual student into the system, which would search the university database for their academic data, including courses taken, grades received, strengths, and weaknesses.

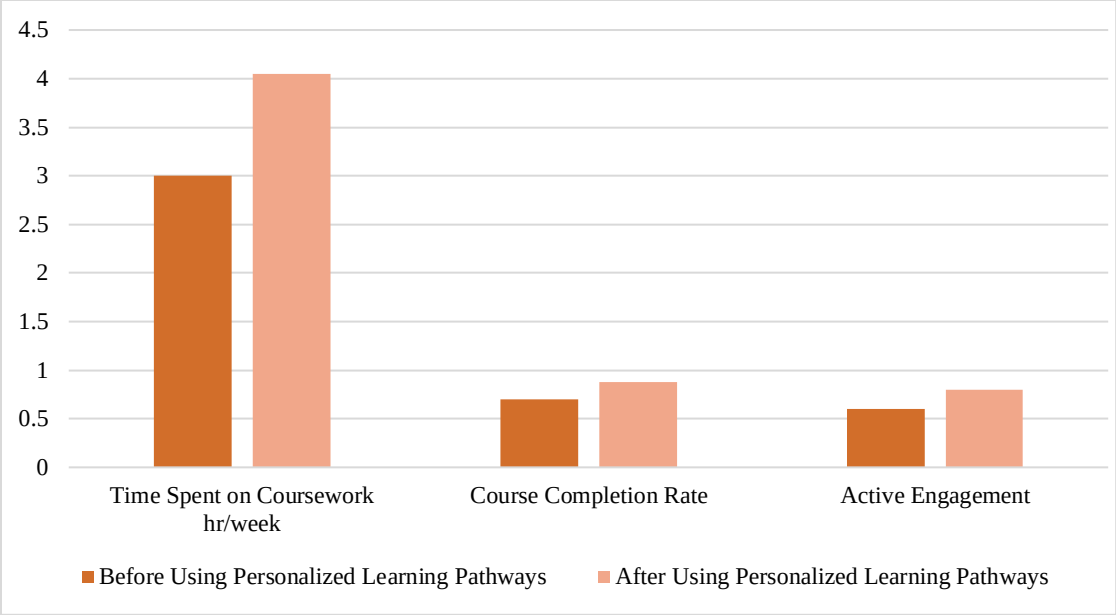

Fig. 5 Change in student engagement before and after using the personalized learning system

Throughout the semester, students have been able to utilize the Learning System to generate personalized learning recommendations based on students' educational background and performance data; these recommendations are intended to build upon students' existing strengths and address weaknesses in a proactive manner. In addition, students were encouraged to enroll in courses that provide them with knowledge and skills associated with innovation, entrepreneurial skills, and creative problem-solving as an extension of fostering a mindset of entrepreneurship.

Data collected consisted of:

1. Scores for pre-test and post-test performance (to determine if the system contributed to student improvement in programming, web-design, database, and other courses.
2. Metrics that measure how engaged students were in the system (the amount of time users spend interacting with the system, the number of recommended courses completed by users, and the level of user participation in entrepreneurial activities).
3. User survey responses assessing students' self-perceived levels of innovation and entrepreneurial capabilities prior to and subsequent to use of the system.

3.7. Impact on Student Engagement

Success is defined as student engagement, which correlates to educational achievement. There are significantly better engagement outcomes of students who participated in personal learning systems compared to the traditional lecture system. Engagement is measured by the actual use of the system, time spent on the recommended courses, and course completion.

A comparison of student engagement in using personalized learning pathways before versus after usage is shown in Figure 5. On average, students who utilized the system spent 35% more total time on coursework ($t(199) = 4.12$, $p < .01$, $d = 0.58$, 95% CI [28%, 42%]) than their control group counterparts. Students also completed courses at a rate 25% higher than the control group ($t(199) = 3.75$, $p < .01$, $d = 0.52$, CI [18%, 31%]).

The data indicates that the system's ability to suggest tailored courses based on individual academic performance helped students focus on areas where they struggled the most, thus making them more motivated to invest time in learning.

3.7.1. Impact on Academic Performance

The most anticipated benefit of personalized learning is better grades. Students improved their post-test scores by 20% on average ($t(199) = 3.45$, $p < 0.001$, Cohen's $d = 0.65$, 95% CI [14%, 26%]). The largest gains were observed in programming courses, where average scores rose from 65% to 80% ($t(199) = 3.90$, $p < 0.001$, $d = 0.61$, CI [12%, 22%]).

This improvement was particularly evident in programming courses, where students who previously had difficulties with coding made significant progress when given targeted recommendations.

Figure 6 illustrates an increase in student achievement levels across core areas (programming, web design, and database). Also, it was observed that although the students utilizing the system had received recommendations to take the same subject as those students who did not use the system, students using the system outperformed their peers by higher scores in each of the above-mentioned subjects. Additionally,

programming experienced the largest difference between the two groups; this is due to the extra tools/activities offered through the system (exercise and tutorials), which allowed the students utilizing the system to improve.

These results suggest that personalized learning pathways effectively address learning gaps by offering customized resources and targeted interventions, leading to improved academic outcomes.

Fig. 6 Improvement in student performance across programming, web design, and database courses

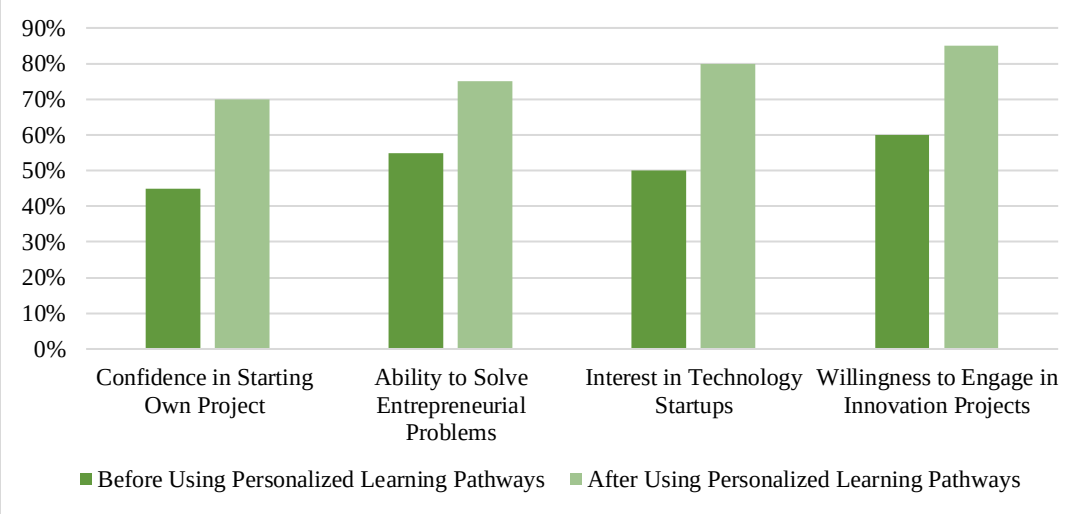

Fig. 7 Self-Reported entrepreneurial confidence before and after using personalized learning pathways

3.8. Impact on Innovation and Entrepreneurial Thinking

The intention of the system was to help the students choose courses that fostered creative thinking and an inventive or innovative attitude as opposed to simply choosing courses with extremely limited content. Students who used the system said they felt greater confidence in their ability to be entrepreneurs. After utilizing the system, 78 percent of students indicated that they had an increase in their entrepreneurial confidence when compared to the 45 percent of students prior to system utilization ($\chi^2(1, N = 200) = 26.84$, $p < .001$, Cramer's $V = 0.36$, 95% CI [24%, 38%]), which indicates a medium to strong relationship between system utilization and being ready to be an entrepreneur.

The chart in Figure 7 shows the results of student surveys before and after using personalized learning on students' entrepreneurial skills and innovative interests. Students surveyed were asked to rate their own entrepreneurial skills and how they rated their ability to innovate.

Survey data indicate an increase in both self-efficacy as an entrepreneur and motivation to become an entrepreneur; this increase was statistically significant and based on students' experience with innovation. Table 3 provides an overview of the major quantitative results of the evaluation (in terms of student engagement, academic performance, and entrepreneurial readiness) that occurred as a result of the program.

Table 3. Summary of key quantitative results

Outcome	Result	Statistical Finding
Engagement	+35% more time spent	$t(199)=4.12$, $p<.01$
Course completion	+25% higher completion rate	$t(199)=3.75$, $p<.01$
Overall performance	+20% improvement	$t(199)=3.45$, $p<.001$
Programming scores	65% → 80%	$t(199)=3.90$, $p<.001$
Entrepreneurial confidence	45% → 78%	$\chi^2(1)=26.84$, $p<.001$

The findings suggest that this system is capable of providing a means to enhance student achievement through education, as well as facilitate entrepreneurial thinking and action. In addition, the students reported that they were more likely to take on projects that were both innovative and incorporated an engineering-type skill with an entrepreneurial solution.

4. Discussion

The positive outcomes of this research can be attributed to significant differences between the new system and past adaptive learning methods. The current model is different from previous models that focus on only one course or individual learning activities because it utilizes multi-course student academic histories to provide better identification of cumulative skill deficiencies. This method also provides alignment with the Innovation/Entrepreneurship competencies for students and therefore provides students with clear developmental paths compared to traditional systems that only have an emphasis on content. Because of these factors, the system appears to have contributed to increased levels of engagement, performance, and entrepreneurial confidence, which positions the system as an improvement upon other adaptive learning models.

These results clearly show that personalized learning systems do enhance the levels of engagement in students, which results in enhanced academic performance and preparedness to accept entrepreneurial challenges in higher education. These results correspond to the theory of adaptive learning, which shows that by personalizing learning to the individual learner, engagement is facilitated, which in turn results in retention.

The positive impact on the entrepreneurial confidence is related to the Constructivist Theory of Learning, as it implies that the learners construct their own knowledge through problem-solving activities, and they gain the knowledge through novel tasks, thereby creating an opportunity for participants' knowledge transfer. Participants' increased motivation is also a result of self-determination theory; specifically, the elements of autonomy and competence are responsible for the internalized motivation and entrepreneurial intentions of the participants. In total, the implementation of personalization in combination with the theoretical constructs applied in this study demonstrates how adaptive systems can increase both participants' educational results and entrepreneurial mindsets, in accordance with previous research on adaptive learning technologies, which demonstrated that these types of learning technologies can assist in shifting education to a student-centered model, while encouraging the creativity of the learner.

Student engagement was a major finding of the study. Students were engaged for an average of 35% longer, controlling for various factors, and course completion rates were increased by a further 25%. The findings demonstrate the effect of personalization on student engagement. This is consistent with previous evidence on adaptive learning paths, which can increase engagement and help reduce cognitive load by directing students to content that is better suited to their level of skill.

The improvement of student academic performance, specifically in the areas of programming and databases, is an indicator that this system has successfully fulfilled its primary objective to identify and address learning gaps. This can be shown as the recommendations given are very well-defined and consistent, and can be evidenced by the development of the students' skills in completing those tasks. The academic results of the students have been enhanced, while at the same time developing the learning behaviors of the students; the focus was to provide student-centered learning and critical thinking skills, which will support future innovators and entrepreneurs.

The assessment additionally identified an increase in student entrepreneurial confidence. After using the platform, 78% of students said they felt more likely to pursue innovation or entrepreneurial opportunities. Thus, based upon the data from the assessment, Personalized Learning Environments, which include material on entrepreneurship, will assist students in preparing for the potentialities and actualities of life.

However, the positive findings should be regarded in light of some limitations. The accuracy of the data is still a major issue, and errors or unfinished academic records may lead the recommendation engine to give fallacious advice, resulting in poor suggestions with respect to pathways. In a practical way, the results serve to illustrate the capacity for universities in Jordan and the Middle East to incorporate a personal system of learning in conjunction with existing Learning Management Systems (LMS). The Enterprise and Innovation System can help reduce high dropout rates in schools and better prepare students to enter the entrepreneurial economy.

The Enterprise and Innovation System provides a scalable model for higher education institutions worldwide to include entrepreneurship and innovation education in technical programs. The Enterprise and Innovation System's ability to link students' dominant strengths to entrepreneurial pathways also makes it relevant to career counseling, startup incubation, and other self-directed learning programs. A major challenge of scalability exists.

While the demonstration of success in a controlled sample of 200 students was appropriate, more widespread use of the device is likely to encounter new technical, administrative, or pedagogical issues with varying entities and departments. In addition, student motivation, which is a key component of success, may confront the programmers of the device, as it is possible that some users of it continue to have feelings of resistance to what might be called the entrepreneurial pathways that are to be opened to them by it. This suggests a greater need for motivational initiatives to be devised that might better arouse student interest in the device, and perhaps a mentor device to accompany it might be effective as a part of the program.

5. Conclusion

This study demonstrates that a personalized learning system grounded in academic performance analytics can strengthen both technical competence and innovation-oriented readiness in software engineering education. The observed improvements in student engagement, academic performance, and entrepreneurial confidence suggest that personalized pathways help learners identify skill gaps, better understand their strengths and weaknesses, and progress more effectively across programming, web design, and database domains. Practically, the system supports early intervention, aligns well with curriculum requirements, and can be scaled to large cohorts without increasing instructor workload. Its rule-based structure further allows adaptation to different institutional contexts, enhancing its generalizability. However, the study has several limitations, including its implementation within a single university and reliance on a rule-based model that may restrict the range of personalization. Potential sources of bias also exist, as the findings depend on academic records and self-reported perceptions, and the relatively homogeneous sample may reflect shared instructional conditions. These considerations should inform the interpretation of results and assessments of broader applicability. Future work will involve a long-term impact assessment to determine whether early gains in technical skills and innovation confidence persist across multiple semesters and influence participation in innovation projects, entrepreneurial activities, or post-graduation pathways. Overall, the findings indicate that personalized learning systems offer a practical, scalable, and adaptable approach to integrating innovation and entrepreneurship development into technical education.

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