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ICT Framework for the Personal Learning Environment (PLE-ICT) in Higher Education: Results from Experts' Interview

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Abstract. The incorporation of Information and Communication Technology (ICT) into higher education has profoundly revolutionized the manner in which students engage with educational resources and acquire knowledge. Personal Learning Environments (PLEs) facilitate a tailored and adaptable learning approach, empowering students to take charge of their own educational experiences. Nonetheless, to effectively leverage PLEs in higher education, a robust ICT framework is imperative. This paper explores the development of an ICT framework specifically designed for PLEs within the context of higher education. The framework encompasses diverse ICT attributes, including accessibility, flexibility, data analysis, extensive capacity, automation, personalization, and security. Analyzing interview data led to the formulation of a PLE-ICT framework prototype, comprising five dimensions: ICT hardware, ICT software, ICT services, project development, and support team. The findings of this study enrich the theoretical comprehension of ICT integration in PLEs and offer valuable insights for the future elaboration of more intricate PLE-ICT scales. The suggested ICT framework delivers a comprehensive and pragmatic blueprint for the implementation of PLEs in higher education institutions, with the potential to augment student learning experiences and outcomes.

Keywords. ICT framework, Personal Learning Environment, PLE, higher education, experts' interview

1. Introduction

With the rapid development of information and communication technology (ICT), higher education has also undergone significant changes, leading to the rise of the

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concept of a Personal Learning Environment (PLE). A PLE is a set of technological tools and resources that an individual learner selects and uses to support their learning activities and goals, in a self-directed and adaptable manner, based on their interests and needs, and with the purpose of building a personal learning network[1]. To construct and implement PLE in higher education, Information and Communication Technology (ICT) plays a crucial role[2]. ICT provides the infrastructure and tools necessary to support learners in managing and organizing their learning experiences and educational resources, including online platforms and digital repositories, social media and communication tools, and personalized learning technologies [3].

Several ICT frameworks and criteria have been proposed to guide the development and implementation of Personal Learning Environments (PLEs) in higher education. One of the most widely recognized frameworks is the Seven Pillars of PLE proposed by Downes [3]. This framework outlines seven critical components of PLEs: ownership and control, aggregation, mixability, reusability, feeding forward, feedback, and potential [3]. Besides, the e-Portfolio Model, as proposed by Attwell [4], emphasizes the role of learners in organizing, reflecting upon, and showcasing their learning experiences and achievements. In this model, ICT tools facilitate the creation and management of digital portfolios, enabling learners to document, track, and share their learning journey with peers, instructors, and potential employers [4]. Moreover, the Connectivist PLE Model, rooted in the connectivism learning theory introduced by Siemens [5], emphasizes the role of networks and connections in the learning process. In this model, learners use ICT tools to access, filter, and evaluate information, as well as to create and share knowledge within their personal learning networks

While the aforementioned PLE models have contributed significantly to the understanding and development of Personal Learning Environments in higher education, there remains a research gap in providing a comprehensive PLE ICT framework that addresses all dimensions necessary for successful construction and implementation. Previous models primarily focused on individual aspects of PLEs, such as personalization, adaptability, self-regulation, collaboration, and networking. However, a holistic PLE ICT framework is needed to ensure seamless integration of all dimensions, including hardware, software, ICT services, project development, and support teams. This research aims to fill this gap by developing a PLE ICT framework that encompasses the complete dimensions of ICT required for constructing and implementing PLEs in higher education. The research question is thus raised:

Question: What are the ICT requirements for the construction and implementation of a PLE in higher education from ICT experts' points of view?

The research context of this study focuses on higher education institutions, where the integration of Information and Communication Technology (ICT) plays a pivotal role in shaping the learning experience. By examining the implementation of Personal Learning Environments (PLEs) within this context, the research seeks to understand how a comprehensive ICT framework can facilitate personalized learning, ultimately leading to enhanced educational outcomes for students.

This study first introduced the ICT resources needed for the construction and implementation of a PLE in higher education, then discussed the concepts and necessity of hybrid cloud, and finally interpreted the ICT characteristics of PLE in higher education. The methodology is then introduced followed by the interview data

analysis. The findings of this study will provide insights into the ICT requirements for implementing a PLE and help the future development of a more detailed PLE-ICT scale for higher education. Additionally, the results of this study will also contribute to the growing body of literature on the use of ICT in higher education and the implementation of PLEs.

2. Review of the ICT requirements for the development of PLE in higher education

A comprehensive understanding of the ICT requirements for constructing and implementing Personal Learning Environments (PLEs) in higher education is crucial for their successful integration into the learning experience. Several studies have explored the essential elements and tools that facilitate effective PLEs [6][1]. Accessibility, flexibility, data analysis, large capacity, automation, personalization, and security have been identified as key ICT features for PLEs [7][8].Additionally, recent research emphasizes the importance of designing PLEs that are adaptable to learners' needs, preferences, and learning styles [9][2]. Furthermore, the integration of cutting-edge technologies such as artificial intelligence, machine learning, and cloud computing has been proposed to enhance the effectiveness and efficiency of PLEs in higher education [10]. It is also crucial to consider the role of social media, collaboration tools, and multimedia resources in supporting the development of connected and engaging learning experiences [11]. In sum, the literature highlights the importance of a well-rounded ICT framework that incorporates various technological dimensions and features to ensure the effective construction and implementation of PLEs in higher education.

2.1 ICT resources needed for PLE in higher education

In order to implement PLEs effectively, ICT resources such as laptops, tablets, smartphones, and other mobile devices are required to provide students with access to the digital learning materials and tools they need to complete their studies. Furthermore, software such as learning management systems (LMS), e-portfolios, social software, and content management systems are necessary to manage, store and share learning materials and to facilitate collaboration among students and teachers.

In addition, communication technologies such as instant messaging, blogs, wikis, and discussion forums are crucial for fostering collaboration and communication among students and teachers. These technologies allow students to exchange ideas and provide feedback on their learning experiences in real-time. By analyzing the most popular online learning platforms, the following part introduced the hardware, software, and service needed for implementing PLE in higher education:

2.1.1 Hardware resources

The hardware source needed for personalized learning environments generally includes both mobile and PC. To ensure smooth system operation, the mobile side can use at least an eight-core processor with memory references ranging from 4 GB to 64 GB

RAM. The operating system only needs to support the latest version of iOS or Android, and the network only needs to have a high-speed internet connection to ensure fast loading and syncing of platform data and resources. The PC side can use at least an Intel Core i5 or similar processor with memory ranging from 8 GB to 256 GB RAM, an SSD notebook or desktop computer, and a display screen with at least 1920x1080 resolution for a good visual experience. The network only needs to have a high-speed internet connection to ensure fast loading and syncing of platform data and resources.

2.1.2 Software resources

An effective ICT framework for PLE in higher education should include software resources that support the learning and development needs of students and educators. Key features to consider in educational software include:

- Well-rated apps for both iOS and Android platforms, allowing students to access the software from their preferred device, including laptops, Chromebooks, and smartphones.
- Automated grading and integration with SpeedGrader to support the assessment process.
- A website builder and customizable templates to facilitate the creation of educational content by educators.
- Project creation tools, including a video editor, plagiarism checker, and assignment tracker to support student learning and engagement.
- Integration with corporate social media accounts.
- Tools for authoring, including text editing and video capture support the creation of multimedia learning materials.

2.1.3 Service resources:

In addition to software resources, an ICT framework for PLE in higher education should also include reliable and user-friendly service resources to support the learning process. Key features to consider include:

- Support for third-party cloud storage providers, such as Dropbox, to ensure the safety and accessibility of educational data.
- The ability to create individualized student pathways via LinkedIn Learning content.
- A white-label approach to foster customization and consistent branding across the educational institution.
- Support for multiple tenants, allowing an administrator to manage multiple accounts with a single set of sign-on credentials.

- Advanced support options, including a forum or FAQ, a robust community forum, and growing scalability.
- An easy-to-use interface with a variety of support options, including direct support via email and phone.

2.2 Hybrid cloud

The hybrid cloud concept has gained significant traction across various industries, including education, as it combines the advantages of both public and private clouds. Hybrid cloud computing, as defined by Srinivasan[12], comprises a mix of on-premises, private cloud, and third-party public cloud services with orchestration and integration between platforms. Key components of modern hybrid cloud architecture include virtualization, data-driven approaches, Software as a Service (SaaS), Industry 4.0 integration, on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service [13][14][15][16][10].

Hybrid cloud offers benefits such as cost efficiency, scalability, flexibility, and security. In the context of PLEs, a hybrid cloud allows institutions to balance cost-effectiveness and scalability with privacy and security for sensitive student data. It also offers flexibility and adaptability, enabling institutions to choose appropriate cloud services and switch between them as needs evolve. Moreover, it enables the integration of advanced technologies such as artificial intelligence and machine learning, enhancing student learning experiences.

The use of mobile devices in higher education is also becoming increasingly popular, with studies showing the potential for mobile devices to improve access to educational resources and facilitate learning [17]. The integration of mobile devices with hybrid cloud infrastructure can further enhance the adaptability and accessibility of PLEs, providing learners with greater opportunities for personalized learning experiences.

The unified hybrid cloud, still in its early adoption phase, demonstrates benefits including scalability, cost efficiency, improved security, increased agility, better compliance, and enhanced collaboration. Papadakis et al. [18] highlight the potential of digital eLearning educational tools, such as ARION, to synchronize, compose, and orchestrate learning session data within a hybrid cloud environment. Although the benefits of a unified hybrid cloud platform depend on an organization's specific needs and the level of integration between different cloud platforms, it holds great potential for optimizing resources and enhancing collaboration across various industries, including higher education.

2.3 The ICT features of PLE in higher education

A review of the literature indicated the following five ICT features of PLE:

- Customizable User Interfaces (CUIs): Manca and Paternò [19] defined CUIs as user interfaces that can be modified according to the needs and preferences of different users. Specifically, CUIs allow users to customize not only the layout and content of the user interface but also its behavior and functionality. In PLE, CUIs can include selecting and arranging the tools and resources that

they need to support their learning, such as course materials, discussion forums, and multimedia resources.

- Social Networking Tools: Social networking tools, such as blogs, wikis, and discussion forums, play an important role in PLE, allowing learners to engage with each other, share information, and collaborate on projects [20].

- Personalized Learning Paths: PLEs can provide learners with the ability to create and manage their own learning paths, enabling them to select and prioritize the resources and activities that best meet their learning needs [21]. This can help to increase learner engagement and motivation, as well as support the development of personalized learning plans that are tailored to each individual's needs and interests.

- Mobile Access: With the increasing prevalence of mobile devices, PLEs need to be designed to support access from a variety of mobile devices, including smartphones and tablets [22]. This can provide learners with the ability to access learning resources and engage in learning activities at any time, from any location, and on any device.

- Learning Analytics: Learning analytics tools play an important role in PLE, providing learners with the ability to track and monitor their learning progress, and receive personalized feedback and support [11]. These tools can also be used to analyze learner data and provide insights into their learning behavior and patterns, helping educators to identify areas for improvement and make more informed decisions about their teaching practice.

3. Method

This study employed semi-structured interviews to explore the essential ICT components and systems for constructing effective and efficient PLE-ICT in higher education. This data-gathering method offers a flexible approach, enabling researchers to adapt questions based on participants' responses, generating in-depth and context-specific insights [23]. Semi-structured interviews are particularly useful when investigating complex phenomena like ICT components in PLEs, as they allow researchers to better understand participants' experiences, perceptions, beliefs, and attitudes [24]. This method is well-suited for exploring ICT requirements for PLEs in higher education, as it helps researchers gather nuanced information and identify commonalities and differences among participants' experiences and opinions [25].

The sampling technique utilized was purposive sampling, selecting five ICT experts with 5-10 years of working experience in PLEs in higher education. A sample size of five interviewees was chosen to ensure a manageable amount of data for in-depth analysis while still providing rich and diverse perspectives on the topic. The diversity of participants in gender, age, and professional background aimed to provide a comprehensive understanding of the ICT components and systems necessary for building an effective and efficient PLE, and to ensure that the resulting framework would be applicable to a wide range of higher education institutions.

The purpose of the interviews was explained to the participants, and they all agreed to have the interview recorded. The average interview time was 30 minutes. The interviews aimed to gather data about the ICT components and systems necessary for building an effective and efficient PLE. The collected data was analyzed and coded to identify common themes and patterns.

Based on the literature review, the interview questions were designed to elicit information about the participants' experiences with PLEs, their understanding of the ICT infrastructure required for PLEs, and their recommendations for an ICT framework that would support PLEs in higher education. The questions were open-ended, encouraging participants to provide detailed information and insights about their experiences with PLEs and their thoughts on the ICT infrastructure necessary to support PLEs (see table 1)

Table 1. Question items and the literature reference

Question items	literature
1. Please describe your experience with PLEs in higher education.	[26]
2. In your opinion, what are the key components of an ICT framework for PLEs in higher education?	[27]
3. What factors should be considered when implementing an ICT framework for PLEs in higher education?	[28]
4. What challenges or limitations have you encountered, or do you anticipate, in implementing an ICT framework for PLEs?	[29]
5. How do you ensure that ICT features in PLEs are accessible to all learners, including those with disabilities and different backgrounds?	[30]
6. How does flexibility in ICT features contribute to the success of PLEs in higher education?	[9]
7. How does data analysis support the development of effective learning experiences in PLEs?	[8]
8. Why is having a large capacity important for the success of PLEs in higher education?	[7]
9. How does automation support the development of more flexible and dynamic learning environments in PLEs?	[31]
10. How do you ensure the personalization of functions within PLEs in higher education?	[6]
11. Please share any best practices you have observed or implemented for the successful integration of an ICT framework in PLEs in higher education.	Self-made
12. What recommendations do you have for institutions seeking to implement an ICT framework for PLEs?	[32]

The data collected from the interviews were transcribed and analyzed using a thematic analysis approach. The transcripts were read multiple times to gain a general understanding of the data. Codes were then generated and applied to the data to identify common themes and patterns. The codes were developed based on the interview questions and the collected data. The data analysis aimed to identify the ICT components and systems necessary for building an effective and efficient PLE.

4. Sample and sampling

This study aimed to develop an ICT framework for Personalized Learning Environments (PLEs) in higher education. To achieve this goal, the study employed a qualitative research design and conducted in-depth interviews with 5 ICT experts with 5-10 years of working experience in PLEs in higher education. The participants were selected based on their professional experience and expertise in the field of ICT and education. All participants held a Ph.D. degree, with two of them being female and three of them being male. Their ages ranged from 35-55.

Before conducting the interviews, informed consent was obtained from all interviewees. They were provided with a written description of the study, including its purpose, methods, and expected outcomes. Participants were also informed of their right to withdraw from the study at any time. They were required to sign a written consent form indicating their agreement to participate in the study. The transcripts of the interviews were coded using a pseudonym to protect the identity of the participants.

5. Results and discussion

The transcribed data from the interviews were analyzed using a thematic coding approach, following a multi-stage process. Initially, the data were subjected to open coding, where common themes and patterns were identified [33]. Next, these themes were grouped into similar ideas and labeled, resulting in the creation of categories [34]. To ensure consistency and accuracy, two coders conducted the coding process independently, and their results were compared. Any discrepancies were discussed and resolved through consensus [35].

Coding categories: The following coding categories were identified and used for analysis.

- Key components of an ICT framework for PLEs
- Considerations for the implementation of an ICT framework for PLEs
- Challenges and limitations in the implementation of an ICT framework for PLEs
- Best practices for the successful implementation of an ICT framework for PLEs

The coded data were analyzed to identify common themes and patterns in the data. The findings from the analysis were used to develop a comprehensive ICT framework for PLEs in higher education, which involved the following seven ICT features of PLE:

1) Accessibility

It can refer to physical accessibility, such as access to the necessary hardware and software, as well as to the usability and user-friendliness of the ICT features themselves [30]. It is also important to consider accessibility in terms of socio-economic factors,

such as the cost of access and the availability of technical support [36]. To ensure that ICT features in PLEs are accessible to all learners, it is necessary to consider the needs of different groups and to design the features to be inclusive and user-friendly [30].

2) Flexibility

It refers to the ease and convenience of ICT deployment, as well as its ability to be recovered and monitored. Moreover, it also involves the ability to adapt to the needs and preferences of each individual learner [9]. This requires the provision of reliable and efficient infrastructure, as well as the development of user-friendly systems and tools [36].Besides effortless implementation, it is essential that ICT components within PLEs can be readily restored in the event of system failures or other technical problems. Finally, ICT features in PLEs should be designed to be easily monitored, allowing for the effective measurement of their impact on learning and for the identification of areas for improvement [36].

3) Data analysis

It enables PLEs to provide detailed information about learners' behavior and learning strategies, as well as to support the continuous improvement of learning experiences [8]. Data analysis in PLEs can include the analysis of learning behavior, such as the types of resources used and the strategies employed to engage with the material [37]. This information can be used to support the development of more effective learning experiences, as well as to identify areas for improvement and track progress over time [8].Furthermore, analyzing data in PLEs can offer significant insights into elements that impact learning, such as motivation, engagement, and self-confidence [37]. This information can be used to support the development of more effective teaching and learning strategies, as well as to identify areas where additional support may be needed to ensure that all learners are successful [8].

4) Large capacity

The ability of an online learning system to handle a large volume of users and data. This could include the ability to process user data and generate personalized recommendations, as well as the ability to store and manage a large number of learning resources [38]. By tracking and storing learners' historical behavior data, personalized recommendation systems can use machine learning algorithms to analyze this data and provide personalized recommendations to learners, helping them achieve their learning goals more effectively [7]. The capacity to save and retrieve learning documents, including notes, assignments, and evaluations, plays a crucial role in creating a significant learning portfolio. The large storage capacity of ICT in PLEs also allows learners to easily access and manage learning resources, such as readings, videos, and multimedia materials [38].

5) Automation

It refers to the use of machine learning algorithms to personalize the learning experience of students without the need for manual intervention by instructors [31].

This feature helps to streamline these processes, making them more efficient and reducing the administrative burden on educators and learners. The use of automated systems in PLEs can also support the development of more flexible and dynamic learning environments.

6) Personalization of functions

It refers to the use of various technologies and methods to adapt learning experiences and materials to individual learners, taking into account their learning styles, interests, and prior knowledge [6]. This feature can support the development of more personalized and effective learning experiences, as learners can tailor their learning environment to their specific needs. The personalization of ICT functions can also support the development of more flexible learning environments, as learners can access and use the tools and resources that best meet their needs and preferences [39].

Security

It includes protecting sensitive student and institutional data. According to a study by Garg and Goel [40], the threats to online assessment security include identity fraud, cheating, and hacking. Security strategies such as multi-factor authentication, proctoring, and machine learning-based approaches are recommended. Furthermore, security measures can prevent unauthorized access to ICT systems, reducing the risk of data breaches and theft of confidential information. It should be pointed out that ICT systems in higher education must comply with various regulations which set strict guidelines for the handling of student records and information.

Based on the literature review and interview data analysis, the researchers constructed the following PLE-ICT framework as a prototype (see Table 2).

Table2. PLE-ICT framework prototype

1. Hardware	**1**	**2**	**3**	**4**	**5**
1.1 Have a Standard Operating Procedure (SOP)					
1.2 Inspection and improvement, adjustment of the SOP					
1.3 User feedback mechanism					
1.4 Expert feedback mechanism					
2. Software					
2.1 Have a Standard Operating Procedure (SOP)					
2.2 Inspection and improvement, adjustment of the SOP					
2.3 User feedback mechanism					
2.4 Expert feedback mechanism					
3. ICT service					
3.1 Have a Standard Operating Procedure (SOP)					
3.2 Inspection and improvement, adjustment of the SOP					

3.3 User feedback mechanism					
3.4 Expert feedback mechanism					
4. Project development					
4.1 Have a Standard Operating Procedure (SOP)					
4.2 Inspection and improvement, adjustment of the SOP					
4.3 User feedback mechanism					
4.4 Expert feedback mechanism					
5. Supporting group					
5.1 Have a Standard Operating Procedure (SOP)					
5.2 Inspection and improvement, adjustment of the SOP					
5.3 User feedback mechanism					
5.4 Expert feedback mechanism					

1	Not implemented: no standardized operating procedures or user and expert feedback mechanism.
2	Planning: plans to establish standardized operating procedures and a user and expert feedback mechanism.
3	Partially implemented: partially in accordance with the standardized operating procedures, with a basic user and expert feedback mechanism
4	mostly implemented: mostly in accordance with the standardized operating procedures, with a relatively complete user and expert feedback mechanism.
5	Fully implemented: fully in accordance with the standardized operating procedures, with a complete user and expert feedback mechanism.

Source: self-generated

As shown in the above table, the main technical indicators of the Personal Learning Environment include five dimensions: ICT hardware, ICT software, ICT services, project development and support team.

Hardware equipment is the foundation for platform operation and is crucial for the efficient and stable operation of the platform [14]. ICT hardware includes servers, storage and bandwidth, and networks. The server is the core of the entire system and is responsible for processing user requests, providing content to users, and personalized services [10]. Storage devices are used to store all user data and content and need to have a large capacity and high read and write speed to ensure that users can access the content they need at any time and anywhere [39]. Bandwidth and network are the communication channels between the platform and users and determine the network speed and stability of users when using the platform.

Software systems are an essential component in personalized learning environments [41]. They are responsible for implementing various functions in the learning environment, ensuring that both students and teachers can learn in an efficient

and stable environment [7]. The ICT software includes systems, tools, and backend management, which together form an efficient and stable learning environment.

Information Technology Service Management (ITSM) is a key factor in personalized learning environments [40]. Its use helps to ensure system reliability, improve service efficiency, and enhance user experience. The main service of ICT refers to ITSM, such as ISO15000, which provides a systematic process and method for service management to ensure service reliability and availability.

The development team is an important support force for the personalized learning platform [16]. It provides users with high-quality technical and service support, ensuring that the platform is always in its best state to better support the users' learning needs. The ICT support team primarily provides technical support such as equipment, video filming, and instructional material development to teachers, students, and administrative staff.

In sum, creating and utilizing PLE in higher education requires attention to five main areas: ICT hardware, software, services, project development, and support team. Hardware such as servers, storage devices, and networks are essential for the PLE's efficient operation. The software implements various functions, ensuring a smooth experience for students and teachers. IT Service Management (ITSM) improves reliability and efficiency, while the project development team ensures the platform meets users' needs. Technical support provides assistance to teachers, students, and staff, ensuring optimal performance. Overall, these dimensions are crucial for constructing and implementing an effective PLE in higher education.

6. Conclusion and limitation

This study presents the development of an Information and Communication Technology (ICT) prototype framework for Personal Learning Environments (PLEs) in higher education from the perspective of ICT experts. The framework considers various ICT features, including accessibility, flexibility, data analysis, large capacity, automation, personalization, and security, as well as the five dimensions of ICT hardware, ICT software, ICT services, project development, and support team. The construction of this ICT framework for PLEs is a significant advancement in providing personalized and flexible learning opportunities in higher education. The proposed PLE-ICT framework provides a prototype framework from the perspective of ICT experts, which offers insights for future detailed PLE-ICT scale development and supports institutions looking to enhance personalized learning experiences in higher education.

Based on the findings, practitioners are recommended to consider the identified ICT features and dimensions when implementing PLEs in higher education settings. This will help ensure that PLEs are accessible, flexible, and capable of providing personalized learning experiences for students.

The study has some limitations: first, only five ICT experts were interviewed, which may not accurately represent the views and perspectives of other stakeholders in higher education, such as teachers and students; second, the semi-structured interview relied on participants' self-reported information, which may be subject to biases and limitations in their perceptions and recall of events. Future research could collect empirical data to enrich and test the PLE-ICT framework.

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