E-Assessment Systems: An Evaluation Framework from the Perspective of Higher Education Experts

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***Abstract*— Assessment represents a central aspect of the learning process. As learning environments become more flexible and unbound by the restrictions of traditional education and as students increase in number and diversity, technology assumes a critical role in the support of a more adequate, scalable and personalised assessment. The employment of e-assessment systems can assist teachers in the development of several e-assessment initiatives, especially at a time when there is an unprecedented migration towards online learning. This paper aims to identify the essential characteristics of effective e-assessment systems by appraising an evaluation framework to assist teachers to select efficient systems. The learning technology and e-assessment experts, who completed an online questionnaire, validated the identification of the key characteristics of effective e-assessment systems: variety of assessment design options, scalability, security, accessibility and usability, feedback features, personalisation, financial cost and interoperability.**

Keywords*— *Learning assessment, e-assessment, information systems education, framework, e-assessment systems, higher education.

I. INTRODUCTION

The higher education sector is progressively implementing e-assessment, as both educators and learners are displaying higher acceptance and adoption rates [1]. E-assessment systems can be defined as systems that assist the creation, delivery and evaluation of e-assessment activities. E-assessment systems have become extremely important as assessment instruments for online learning environments. They are valuable instruments in the provision of personalised feedback to and mentoring of students. Moreover, they represent an automated solution with clear benefits in the context of large numbers of students and for assignments that might have more than one correct answer [2].

E-assessment systems, such as e-exams systems, represent an important support for e-assessment in the sense that they allow for marking automation, they offer various options in terms of question authoring, they enhance exam logistics and are a valuable source for learning analytics [3]. In a study by Guitart Hormigo, et al. [4] the authors examine the integration of dashboards within e-assessment systems to assist the decision-making process of teachers. E-assessment systems include systems for self-assessment, which students can use to assume a greater control over their learning process, and for self-intervention based on feedback [5]. In addition, e-assessment tools, such as e-portfolios, can actively contribute to the students development of digital competencies [6].

E-assessment systems are especially relevant in this era of Massive Open Online Courses (MOOC) proliferation [7] and they can be a valuable ally in the current context of massive education displacement to online settings, due to the COVID-19 pandemic [8, 9]. The use of e-assessment is expected to rise and the Covid-19 pandemic will probably intensify its use [10]. They include several e-assessment platforms and they can assume a variety of designs. As the needs of higher education evolve, so do e-assessment systems. Current e-assessment systems described in the literature [11-14] incorporate innovative technology, such as face recognition, plagiarism detection, and cloud computing, to address the needs of both teachers and students as they become more complex. While the existing assortment of available systems widens the possibilities of e-assessment delivery, it can equally constitute a challenge for teachers and institutions with concern to selecting the most appropriate system and deciding which features are required to support, create, and deliver e-assessment activities. It is therefore, essential to explore the characteristics that are fundamental for effective e-assessment systems.

Despite the importance of the selection of an appropriate e-assessment system, in a context of increasing variety, there is a lack of research that can assist teachers in making this decision and explore the criteria of an efficient e-assessment system. Hence, this paper addresses one research question: What are the core characteristics that an ideal e-assessment system should have to successfully support higher education e-assessment? This paper will firstly approach e-assessment systems improvement and evaluation. The methods section ensues and precedes the description, analysis and discussion of the results. The paper concludes with an overview of its limitations and the expectations for future research ventures.

II. IMPROVING E-ASSESSMENT SYSTEMS

In the context of higher education, despite a growing acceptance of e-assessment [1], the COVID-19 pandemic period showed that the institutions lacked preparation in terms of a more widespread incorporation of e-assessment [15].

Research on e-assessment systems reveals a growing concern for the incorporation of more ample features, to address some of the challenges that are encountered when resorting to these systems and to widen the possibilities afforded by the systems. Iftikhar, et al. [11] propose an e-assessment system that addresses two core challenges of design: the communication of progress to the students and the need to maintain student motivation and engagement. The authors report on the development of the Learning Intelligent System (LIS), an e-assessment system focusing on personalised feedback, whose design was positively evaluated by the students. Personalisation was also a significant concern of the TeSLA (Adaptive Trust-based e-Assessment System

for Learning) European project, although the focus was on security, through authentication. The system that is proposed by this project uses biometric instruments, such as facial and voice recognition and keystroke dynamics, and textual analysis resources, which include plagiarism detection and forensic analysis. Another important characteristic of this system is interoperability. It is implemented through a Learning Tools Interoperability (LTI) plugin, ensuring its integration with any virtual learning environment (VLE) [12].

The e-assessment system proposed by Hajjej, et al. [13], Cloud-AWAS, accounts for personalisation and interoperability and it is based on a cloud computing environment. The architecture of the system that the authors describe is based on cloud services. The cloud services are used to adapt the assessment activities to the profile of the students, which is obtained through their data. The development of this e-assessment system also accounted for the need for interoperability and it is, therefore, possible to integrate it into various learning management systems (LMS). The variety in the array of questions that an e-assessment system can support is an important element of its effectiveness. Attributing a grade and generating feedback for open design exercises, such as diagrams, brief essays or program code is a complex task for e-assessment systems and require a specific architecture. JACK, an e-assessment system, can be used in this type of e-assessment activities. It can be used not merely as a grading instrument for these exercises, but it is equally valuable in the provision of textual feedback to specifically assist the learners to improve their outcomes [14]. The JuxtaLearn system, described by Adams and Clough [16] was developed to support the creation of quizzes for assessment, based on pedagogical approaches. It was designed to support the e-assessment process in three phases, using specific instruments to assist teachers in the creation of the quizzes that are pedagogically sound; incorporating the quizzes into the students' personalised learning paths; and providing feedback both to the students and to the teachers to direct learning.

III. EFFICIENT E-ASSESSMENT SYSTEMS

The abundant offer of e-assessment systems can encumber the selection of the most appropriate system, by teachers. There is a lack of research in terms of e-assessment systems' evaluation. Solely a few studies have examined e-assessment systems from the perspective of their quality and essential characteristics. Chirumamilla and Sindre [3] study examined the key features of e-exams systems, but from the perspective of vendors and managers. Their findings emphasised functional features such as authoring and grading and non-functional features like usability, integrity, interoperability and security. Although this contribution makes a valuable addition to the current body of literature it excludes the opinions of the teachers. Singh and de Villiers [17] study focuses on the evaluation of e-assessment systems by proposing a framework composed of 11 categories, divided into two groups, functional and non-functional, and with 182 criteria. The categories, question editing, assessment strategy, test and response, test bank, question types, interface, security, compatibility, ease of use, robustness and technical support, offer a conceptual mapping of requirements. Despite its valuable contribution, this framework is limited to a specific type of system, multiple choice questions systems. In an effort to provide some structure and guidance to the evaluation of e-assessment systems, this paper appraises the framework proposed by Isaias, et al. [18] for the selection of efficient e-assessment systems, combining eight key categories of features: variety of assessment design options, scalability, security, accessibility and usability, feedback features, personalisation, financial cost and interoperability.

IV. METHODS

Based on this study's research question, a quantitative methodological approach was deemed more appropriate. This type of approach enables the assessment of theories through the examination of measurable variables. In terms of research design, this study resorted to survey research for its value in collecting quantitative data on the viewpoints of a particular population [19] and it was used in this research via the design of an online questionnaire. The use of an online questionnaire was justified by the fact that the population was geographically dispersed, the various advantages that it presents at the level data entry and storage and the accessibility to the responds [20]. Using convenience sampling [21] the respondents were selected from an international population of teachers and researchers, who were invited to participate for their expertise in the higher education sector. Convenience sampling has some limitations, but certain steps can minimise them, such as selecting as many participants as possible [22], which was performed in this research. The online questionnaire was divided into two sections. The first section was designed for the collection of data related to the demographic profile of the respondents and their experience with e-assessment systems. In the second section, the respondents were required to use an adapted Likert scale (1 to 5 ratings) to convey their level of agreement with the items that related to the proposed framework. Each item pertaining to the different elements of the framework was the result of an integrative literature review [23]. This literature review was equally the basis for the creation of the remaining questions in the questionnaire. The pilot questionnaire was sent to a small group of respondents to assess and perfect its design. The final version was sent to the selected sample by email invitation through the SurveyMonkey platform.

The data analysis, in SPSS 20, had two stages. The first preliminary analysis comprised descriptive statistics, such as the calculation of frequencies, mean and standard deviation values, to portray the general opinion of the experts. The second step in the analysis consisted of a factor analysis of the Likert scale questions pertaining to the framework, in order to simplify and reduce the data to the most relevant items.

V. RESULTS

In total 231 complete responses to the questionnaire were considered valid for analysis.

A. Participants' profile

The sample was composed by 55% of male participants and 45% of female participants. With respect to their age, it was widely distributed: 3% were under 30; 43% were 30-50; 51% were 51-70, and 3% were over 70 years old. The questionnaire's online distribution to an international sample produced responses from 37 countries, such as UK, Germany, Italy, Greece, Portugal, Canada, USA and Australia.

The participants' professional profile was determined by 74% of teaching positions, namely professors (27%), associate professors (18%), senior lecturers (13%) and lecturers (10%). The remaining respondents held research

related professions (14%) or specified other positions (11%), such as assistant dean, curriculum developer and e-assessment development manager.

Besides their professional profile, it was essential to determine their familiarity with e-assessment systems (figure 1).

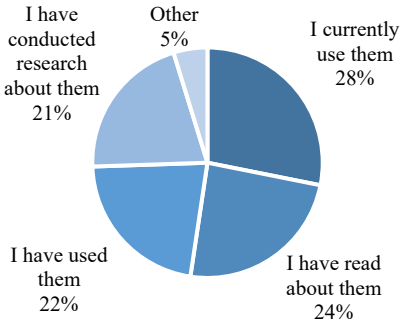

Fig. 1. Respondents' level of familiarity with e-assessment systems

In order to qualify to answer the remaining items on the questionnaire pertaining to the framework, the respondents had to, at least, have read about e-assessment systems, which all the participants had. As figure 1 illustrates, the majority of the sample has a considerable familiarity and an extensive experience with e-assessment systems, which speaks to the validity and adequacy of their contribution to this questionnaire and their evaluation of the framework.

B. Characteristics of efficient e-assessment systems

The last part of the questionnaire required the participants to assess each of the characteristics of the framework, by stating their agreement or disagreement with several related statements, using a Likert scale. All the characteristics of the framework were supported by the viewpoint of the respondents in general, as is illustrated in table 1 displaying the mean and standard deviation calculations.

TABLE I. MEAN AND STANDARD DEVIATION FOR ALL THE CHARACTERISTICS OF THE FRAMEWORK

Framework characteristics and items	Mean	SD
Variety of Assessment design options		
Have a variety of question edition tools (ex. grammar, spellcheck)	4.11	0.79
Provide teachers with different assessment instruments (ex. portfolios, surveys)	4.40	0.75
Allow the design of several question types	4.61	0.60
Incorporate authentic assessment tasks, for example via simulators and games	4.21	0.85
Allow the use of multiple assessment techniques (ex. peer-assessment, self-assessment)	4.35	0.78
Scalability		
Assists an institutional-wide implementation	4.07	0.76
Can be facilitated by automation	4.08	0.85
Allows the delivery of assessment to a higher number of students	4.34	0.71
Can be improved by the use of cloud computing solutions.	3.83	0.92
Enables the delivery of a growing number of assessments	4.07	0.84
Security		
Be required to have options to identify and avoid students' unauthorised behaviour	4.26	0.78
Benefit from the existence of features for the management of personal and assessment data (ex. safe storage, privacy, integrity)	4.32	0.69
Use IP address restriction options	3.64	1.07
Employ student authentication solutions (ex. Personal credentials, video, biometrics)	3.97	0.87
Have features for question randomisation and versioning	4.32	0.79
Be required to have options to restrict/interdict access to the internet/network during assessment activities	4.02	0.98
Accessibility and Usability		
Are conditioned by ease of use	4.22	0.73
Improve with the existence of help options	3.94	0.80
Benefit from the inclusion of a variety of features for promoting access (ex. font size and colour edition, audio transcriptions, subtitled videos)	4.13	0.72
Are enhanced by the incorporation of training functionalities	3.90	0.83
Require their compatibility with most operating systems and devices	4.45	0.68
Demand the provision of technical support	3.89	0.91
Feedback features		
Deliver feedback information to both students and teachers	4.53	0.66
Guarantee students' access to their previous results	4.28	0.82
Include options for the management of assessment data (ex. documentation, statistical analysis)	4.48	0.66
Provide students with an overall depiction of their peers' results	3.66	0.93
Employ automated grading	3.87	0.91
Be required to have mechanisms for answer acceptance (ex. dealing with misspelling, case sensitivity)	4.12	0.80
Personalisation		
Is a fundamental requirement of these systems	3.92	0.89
Can assist teachers to develop more suitable assessment activities through the inclusion of adaptive testing	4.19	0.74
Should include configurations to adapt them to the assessment needs of teachers and institutions	4.20	0.77
Is in great part assured by their ability to deliver adaptive assessment activities	3.83	0.89
Financial Cost		
It is essential that they are financially effective	4.06	0.84
It is better to resort to LMSs for e-assessment than to use specialised e-assessment systems	3.17	1.06
It is more important to select a system that is open source	3.50	1.03
LMSs should not be used for e-assessment activities because the features they offer are limited	2.78	1.00
A commercial system is preferable to an open source alternative, if the assessment design options are more advanced	2.94	1.06
Interoperability		
It is an ideal characteristic of these systems	4.13	0.69
It can be improved through the development of common standards	4.13	0.68
It can assist the integration with other systems and educational applications	4.19	0.67
It is important to assist the incorporation of different data sources	4.12	0.72

An overall analysis of the mean values for the different characteristics of the framework reveals its general validation by the sample of experts. The first element of the framework, variety of design options, registered agreement levels (combination of totally agree and agree ratings) from 81% to 96%. In addition, all the items had a mean of 4.11 or over,

with the respondents highlighting the importance of being able to design several question types. In terms of scalability, the items agreement levels varied from 61% to 90% and the participants underlined the fact that it allows the delivery of assessment to a higher number of students. Although scalability had lower means, the values are still significant (M = 3.83 to 4.34) and the standard deviation remained inferior to 1 (SD = 0.71-0.92). With concern to security, its items gathered an agreement percentage from 72% to 90%, with the exception of IP restriction options (54%). The responses reflected varying opinions with regard to the limitation of IP addresses, with 33% of neutral ratings and 13% of disagreement (combination of totally disagree and disagree ratings). The participants underlined the existence of features for the management of personal and assessment data (ex. safe storage, privacy, integrity) and the inclusion of options that allow question randomisation and versioning. As the other elements of the framework, accessibility and usability were validated by an expressive majority of agreement levels (72% - 92%). The lower mean values for help options, training functionalities and technical support, can be explained by the significant levels of neutral ratings (between 20% and 23%). The fact that e-assessment systems should be compatible with most operating systems and devices was the item that the respondents highlighted as being more important.

Feedback is an integral part of e-assessment systems and the respondents clearly supported this argument in the questionnaire. All items were assigned agreement ratings between 58% and 96%. The provision of feedback to both students and teachers and the presence of options for assessment data management, were highlighted as the most relevant aspects of feedback. The aspect that received less agreement concerns the provision of an overall depiction of peers' results. Not only it had a high neutral score (30%), but also 11% of the participants disagreed with this proposition. Personalisation was deemed as an essential characteristic of e-assessment systems by the respondents, having attributed to it ratings of agreement ranging from 66% to 85%. Examining the mean values reveals the predominance of two items: the inclusion of configurations to adapt the systems to the needs of both teachers and institutions and the existence of adaptive testing. In addition, it is important to underline the fact that 29% of the respondents assigned a neutral rating to the item that states that personalisation is a fundamental requirement of e-assessment systems.

With concern to the financial cost of e-assessment systems, while 75% of the respondents agreed that the systems need to be financially effective, the extent to which they were willing to sacrifice advanced assessment options, for financial reasons, was unclear. Although 47% agreed that it is more significant to select an open source system, 39% were neutral and 13% disagreed. Also, when asked if a commercial system is preferable to an open source alternative, if the assessment design options are more advanced, there was only 29% of agreement, 39% of the responses were neutral and there was 31% of disagreement. Moreover, only 32% of the participants agreed that it is better to resort to LMSs for e-assessment than to use specialised e-assessment systems and solely 22% of the sample was in agreement with the fact that LMSs should not be used for e-assessment activities because the features they offer are limited. The final characteristic, interoperability, had the lowest disagreement rates, ranging from 0% to 0.4%. With respect to the ratings pertaining to agreement, interoperability registered percentages from 81% to 85%. This characteristic of e-assessment systems was also the one with less variability among the items, with a minor predominance of the item relating to interoperability's ability to assist the integration with other systems and educational applications.

Factor analysis

The questions pertaining to the framework, measured with a Likert scale were further analysed and the descriptive statistics was complemented with a factor analysis, which was used due to its ability to outline clusters of variables that provide an understanding of the elements of a group of variables and its capacity to define if the several measures under study are a product of the underlying variable [24]. Factor analysis assists researchers "in identifying and/or understanding the nature of the latent constructs underlying the variables of interest" [25]. In order to determine the viability of this analysis it was important to explore the factorability of the 41 items measured by the Likert scale. The Kaiser-Meyer-Olkin test was conducted and resulted in a value of 0.842, which is above the recommended 0.5 value [24] and the Bartlett's test of sphericity returned a 0.000 value, which means it is significant, as it must be lower than 0.05 [24] and that the data isn't normally distributed. The communalities table was also used and showed that all the values were above 0.3, which indicated that all the items shared some common variance. The fact that in the anti-image correlation matrix all the diagonals were over 0.5 was equally supportive of including all items.

The factor analysis included all items, as per the abovementioned tests and criteria and it was performed using the Principal Component Analysis (PCA) extraction method and the Varimax orthogonal rotation. PCA is likely one of the most popular and old multivariate statistic techniques which aims to simplify and reduce data, by extracting only the most relevant information, and provide an analysis of the structure of the variables and observations [26]. The varimax is one of the most frequently used methods of orthogonal rotation and offers high quality interpretation results [27]. In the factor analysis the percentage of total variance was examined and based on a visual interpretation of the scree plot below, and on the eigenvalues (>1) of the items, 13 main components were extracted (figure 2).

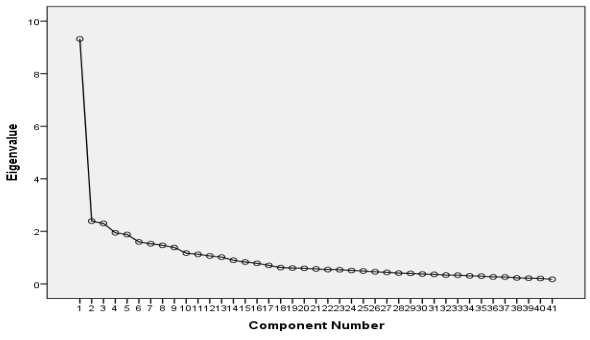

Fig. 2. Scree Plot for all items

The scree plot facilitates the visual detection of the factors that will be extracted for consideration. In examining the rotated component matrix table it was possible to interpret the extracted components by connecting them to the several items, using their factorial weight. Sorting the data by size

provided a clear depiction of each component, being that the majority was associated with clear clusters of items:

- Component 1, which alone explained 23% of the total variance was connected to the interoperability items, all four items had high factor loadings, with a predominance of the item stating that interoperability is an ideal characteristic of e-assessment systems (0.817);
- Component 2 was associated with a cluster of all the items in the personalisation characteristic, with the highest factor loading attributed to the item "can assist teachers to develop more suitable assessment activities through the inclusion of adaptive testing" (0.811);
- Component 3 corresponded to the group of all items pertaining a variety of design options and was led by the item "incorporate authentic assessment tasks, for example via simulators and games" (0.819);
- Component 4 was linked to all the items related to security, with a highlight to the item "be required to have options to restrict/interdict access to the internet/network during assessment activities" (0.759);
- Component 5 gathered the items that compose the accessibility and usability element of the framework, where the item with the highest factor loading was "are enhanced by the incorporation of training functionalities" (0.717);
- Component 6 was linked to a cluster of three of the scalability items, where the item "can be facilitated by automation" was prevalent (0.779);
- Component 7 gathered a cluster of four items from feedback features, led by the item "guarantee students' access to their previous results" (0.743);
- Component 8 was connected to the remaining items for scalability, with the item "can be improved by the use of cloud computing solutions" registering the highest factor loading (0.734);
- Component 9 gathered items of different elements of the framework, but among them, the item with the highest factor loading was "demand the provision of technical support" (0.752), pertaining to accessibility and usability;
- Component 10 was connected to both financial cost and security, but had a prevalence of the item "it is better to resort to LMSs for e-assessment than to use specialised e-assessment systems". (-0.706), which belongs to the financial cost element;
- Component 11 was associated with two financial cost items, with the prevalence of the item "LMSs should not be used for e-assessment activities because the features they offer are limited" (0.870);
- Component 12 gathered three items from feedback features, from which the item "employ automated grading (0.782) registered the highest factor loading;
- Component 13 was linked to two items of financial cost, with the predominance of the item "it is more important to select a system that is open source (0.825).

Together, these 13 components explain 69% of the total variance. Also, all the eight elements of the framework were contemplated in these 13 factors, reiterating the importance of each of them as characteristics of efficient e-assessment systems. The elements of the framework which were more divided between the components were financial cost, followed by feedback features, scalability and accessibility and usability. In the preliminary statistical analysis, these elements of the framework showed more variability among its items.

VI. DISCUSSION

This paper intended to address one research question: what are the core characteristics that an ideal e-assessment system should have to successfully support higher education e-assessment? The analysis of the respondents' input highlighted the importance of each of the eight elements of the proposed framework. Variety of assessment systems was mainly important for the possibility of incorporating authentic assessment tasks, such as simulators and games. This underlines the significance of this type of e-assessment and the importance of harnessing the potential of technological instruments beyond their mere electronic reproduction of paper based assessment. According to the results of the factor analysis, scalability can benefit both from automation and the use of cloud computing solutions, as some developers are already incorporating in e-assessment systems [13]. These options facilitate the delivery of e-assessment activities, and account for and ensure that higher numbers of students or courses, or an increase in assessment frequency will still be viable in the system. It anticipates and addresses progression. For the security element, the most significant aspect was the requirement to have options to restrict/interdict access to the internet/network during assessment activities, underlying the remaining concern that electronic tools can be used to gain access to the solutions of the assessment activities illicitly. The preservation of the integrity of the assessment process is crucial. With respect to accessibility and usability the focus was placed on the integration of training functionalities and the provision of technical support, which corroborates previous findings [17]. The level of comfort with an-assessment system is key both for teachers, in the sense that it will greatly affect the type of e-assessment that they can create, and for the students, who need to focus on completing their assignments rather than to feel anxious about how to use the system.

As was posited by Singh and de Villiers [17] and Weir, et al. [10], the results also show that feedback features should employ automated grading and ensure that the students have access to their previous results. The provision of prompt feedback is one of the most significant benefits of using e-assessment, as it offers students insight into their responses and allows them to refer back to it to visualise their progress. Personalisation, in its turn, was highlighted for its capacity to support the teachers in the development of more suitable assessment activities through the inclusion of adaptive testing. Adapting learning to each of the students is, again, one of the possibilities that only the deployment of technology can make viable. With concern to financial cost, the importance of selecting a system that is open source became evident. Also, in terms of the deployment of LMSs for assessment, it was established that they should not be used for e-assessment activities because the features they offer are limited and that it is not better to resort to LMSs for e-assessment than to use specialised e-assessment systems. Finally, in term of

interoperability, the respondents, in line with Hajjej, et al. [13] and Okada and Whitelock [12] describe it as an ideal characteristic of these systems, which is aligned with a continuous branching of learning to various environments and systems. As e-assessment becomes dispersed to several platforms and systems, it becomes evident that the communication between these different instruments is essential.

VII. CONCLUSION

E-assessment systems are determinant for the delivery of effective and valuable learning assessment and their characteristics can either narrow or widen the possibilities for developing innovative assessment strategies and activities. This study contributes to research with empirical evidence of some of the key features of e-assessment systems and to practice with a guide to assist both teachers and systems developers' decision-making. Despite the insight that the results provided, it is necessary to examine the limitations of this research. The sampling methods that were selected prevent the generalisation of these results. With regards to the use of an online questionnaire, while it represents various advantages, it can provide limited insight into certain aspects of the research. In this particular case, it failed to explain the reason behind certain choices, namely the high number of neutral responses associated with some of the items.

In future research ventures it is fundamental to complement this study with input deriving from qualitative data, namely semi-structured interviews. By engaging the experts in a more in-depth analysis of the elements of the proposed framework, important information can be added to justify the importance of each of the elements. Since, the use of e-assessment systems is associated with several challenges, it would be valuable in the future to examine the impediments of their implementation. Finally, as e-assessment systems impact other stakeholders, such as students and higher education institutions, their viewpoints should also be considered in forthcoming studies.

REFERENCES

[1] P. Miranda, P. Isaias, and S. Pifano, "E-assessment: tools and possibilities for electronic assessment in higher education," in *Proceedings of the 11th International Conference on Education and New Learning Technologies (EDULEARN19)*, ed Palma, Spain: IATED, 2019, pp. 7431-7438.

[2] M. Ullrich, M. Forell, C. Houy, P. Pfeiffer, S. Schüler, T. Stottrop*, et al.*, "Platform Architecture for the Diagram Assessment Domain," in *Software Engineering (Satellite Events), Lecture Notes in Informatics (LNI) 2021*, Bonn, 2021.

[3] A. Chirumamilla and G. Sindre, "E-exams in Norwegian higher education: Vendors and managers views on requirements in a digital ecosystem perspective," *Computers & Education,* vol. 172, p. 104263, 2021/10/01/ 2021.

[4] I. Guitart Hormigo, M. E. Rodríguez, and X. Baró, "Design and Implementation of Dashboards to Support Teachers Decision-Making Process in e-Assessment Systems," in *Engineering Data-Driven Adaptive Trust-based e-Assessment Systems: Challenges and Infrastructure Solutions*, D. Baneres, M. E. Rodríguez, and A. E. Guerrero-Roldán, Eds., ed Cham: Springer International Publishing, 2020, pp. 109-132.

[5] F. Bayrak, "Investigation of The Web-based Self-Assessment System Based on Assessment Analytics in Terms of Perceived Self-intervention," *Technology, Knowledge and Learning,* 2021/04/04 2021.

[6] M. Bearman, J. H. Nieminen, and R. Ajjawi, "Designing assessment in a digital world: an organising framework," *Assessment & Evaluation in Higher Education,* vol. 48, pp. 291-304, 2023.

[7] D. Vomvyras, A. Andreatos, and C. Douligeris, "Exam Wizard: A novel e-assessment system," in *4th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM)*, ed: IEEE, 2019, pp. 1-6.

[8] Z. Yan, "Unprecedented pandemic, unprecedented shift, and unprecedented opportunity," *Human Behavior and Emerging Technologies,* vol. 2, pp. 110-112, 2020.

[9] P. Isaias, P. Miranda, and S. Pifano, "Framing social media and web-based communities within the COVID-19 pandemic: enduring social isolation and subsequent deconfinement," *International Journal of Web Based Communities,* vol. 17, pp. 120-134, 2021.

[10] I. Weir, R. Gwynllyw, and K. Henderson, "A case study in the e-assessment of statistics for non-specialists," *Journal of University Teaching & Learning Practice,* vol. 18, p. 05, 2021.

[11] S. Iftikhar, A.-E. Guerrero-Roldán, E. Mor, and D. Bañeres, "User Experience Evaluation of an e-Assessment System," in *International Conference on Human-Computer Interaction*, 2020, pp. 77-91.

[12] A. Okada and D. Whitelock, "An Evaluation Methodology Applied to Trust-Based Adapted Systems for e-Assessment: Connecting Responsible Research and Innovation with a Human-Centred Design Approach," in *Engineering Data-Driven Adaptive Trust-based e-Assessment Systems*, ed: Springer, 2020, pp. 239-265.

[13] F. Hajjej, Y. B. Hlaoui, and L. J. B. Ayed, "Adapted E-Assessment System Based on Cloud Computing," in *IEEE 17th International Conference on Advanced Learning Technologies (ICALT)*, ed: IEEE, 2017, pp. 251-255.

[14] M. Striewe, "An architecture for modular grading and feedback generation for complex exercises," *Science of Computer Programming,* vol. 129, pp. 35-47, 2016/11/01/ 2016.

[15] C. St-Onge, K. Ouellet, S. Lakhal, T. Dubé, and M. Marceau, "COVID-19 as the tipping point for integrating e-assessment in higher education practices," *British Journal of Educational Technology,* vol. 53, pp. 349-366, 2022.

[16] A. Adams and G. Clough, "The e-assessment burger: supporting the before and after in e-assessment systems," *Interaction Design and Architecture (s),* vol. 25, pp. 39-57, 2015.

[17] U. G. Singh and M. R. de Villiers, "An evaluation framework and instrument for evaluating e-assessment tools," *The International Review of Research in Open and Distributed Learning,* vol. 18, 2017.

[18] P. Isaias, P. Miranda, and S. Pífano, "Framework for the analysis and comparison of e-assessment systems," in *ASCILITE 2017-Conference Proceedings-34th International Conference of Innovation, Practice and Research in the Use of Educational Technologies in Tertiary Education*, H. Partridge, K. Davis, and J. Thomas, Eds., ed: Australasian Society for Computers in Learning in Tertiary Education (ASCILITE), 2017, pp. 276-283.

[19] J. W. Creswell and J. D. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*, 5th ed. Los Angeles: Sage, 2018.

[20] M. Nayak and K. Narayan, "Strengths and weaknesses of online surveys," *Technology,* vol. 6, pp. 0837-2405053138, 2019.

[21] P. J. Lavrakas, Ed., *Encyclopedia of Survey Research Methods*. Thousand Oaks, California: Sage Publications, 2008, p.^pp. Pages.

[22] S. J. Stratton, "Population research: convenience sampling strategies," *Prehospital and disaster Medicine,* vol. 36, pp. 373-374, 2021.

[23] H. Snyder, "Literature review as a research methodology: An overview and guidelines," *Journal of Business Research,* vol. 104, pp. 333-339, 2019/11/01/ 2019.

[24] A. Field, *Discovering statistics using IBM SPSS statistics*, 4th ed.: Sage, 2013.

[25] D. L. Bandalos and S. J. Finney, "Factor analysis: Exploratory and confirmatory," in *The reviewer's guide to quantitative methods in the social sciences*, ed: Routledge, 2018, pp. 98-122.

[26] H. Abdi and L. J. Williams, "Principal component analysis," *Wiley interdisciplinary reviews: computational statistics,* vol. 2, pp. 433-459, 2010.

[27] C. Acal, A. M. Aguilera, and M. Escabias, "New modeling approaches based on varimax rotation of functional principal components," *Mathematics,* vol. 8, p. 2085, 2020.