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Digital assessment formats in higher education: an empirical analysis of the process efficiency of e-assessments compared to paper-pen exams

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ABSTRACT

Digitalization is reshaping higher education, including the way examinations are designed and administered. Electronic assessments (EA) are widely regarded as promising tools to enhance process efficiency. This article presents the findings of a mixed-methods study conducted at Zurich University of Applied Sciences (ZHAW), comparing traditional paper-pen exams (PPE) and EA across both multiple-choice (MC) and open-question (OQ) formats. Using a process cost analysis across three modules (n>700), supported by interviews and student surveys, the study investigates time, cost, and acceptance outcomes. Results show that EA with MC formats yield substantial efficiency gains—reducing overall costs by up to 85%—primarily due to automation in grading and archiving. However, for OQ formats, digitalization provides only marginal cost benefits, as manual grading remains a major cost driver. The study offers nuanced insights into the process dynamics of digital exams and emphasizes that the economic advantages of EA strongly depend on exam format and institutional implementation strategies.

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1. INTRODUCTION

Digitalization is profoundly transforming universities – not only in teaching and research, but increasingly also in examination practice. The introduction of electronic assessments (EA) is currently being discussed in many degree programs. This refers to electronic examination formats that, through digital technologies, not only make existing processes more efficient but also open up new didactic possibilities. They promise efficiency gains, flexibility, and a modern implementation of assessments – aspects that are of key relevance both in undergraduate studies and in continuing academic education. The COVID-19 pandemic has massively accelerated this trend [1]–[4]. In the age of digitalization, universities are expected not only to impart knowledge but also to be competent in using digital examination instruments. Much of the research to date has focused on didactic and technical aspects of EA, such as question formats, feedback functions, or examination validity, as well as on the qualitative development of examinations through digital formats – e.g., multimedia tasks or adaptive feedback [5]–[7]. However, the economic and organizational impacts have been less systematically investigated – especially in comparison to traditional paper-and-pencil exams. The literature so far lacks empirical studies on process efficiency across all phases of the examination process

[8], [9]. Especially in fee-based continuing education programs, where exams are often organized part-time, modular, and resource-conscious, but also in resource-constrained degree programs, efficiency in the sense of time, cost, and quality advantages is a key argument for or against choosing a particular examination format. The question of this efficiency is gaining particular importance.

Efficiency in higher education is usually understood in the context of output-input ratios: how many resources (time, personnel, and money) must be used to achieve a certain outcome (e.g., exam success, proof of competency, and student satisfaction)? With regard to examinations, efficiency is particularly relevant when a large number of students, limited personnel resources, and high demands for legal certainty and quality coincide. EA are considered a response to these challenges in research. Previous work by Redecker and Johannessen [10] has shown that digital assessment formats enable new forms of competency measurement – e.g., through simulation-based questions, interactive tasks, or multimedia elements. Furthermore, EA are easier to standardize and centrally administer, which is particularly advantageous for continuing education institutions. While benefits such as faster feedback, better scalability, and logistical advantages have been well documented, less attention has been paid to the process costs and efficiency across different types of question formats. In particular, the economic differences between multiple-choice (MC) and open-question (OQ) formats in both paper-pen exams (PPE) and EA modes remain underexplored.

Despite this development, the process efficiency of EA compared to traditional PPE remains an under-researched topic. While there are numerous studies on issues of validity, usability, and acceptance, comprehensive analyses that capture the entire assessment process in its economic dimension are lacking [11]–[13]. This study contributes to this by conducting and evaluating three field experiments with over 700 students at the Zurich University of Applied Sciences (ZHAW). The objective of this study is to conduct a comprehensive analysis of the examination process—covering conception, implementation, grading, and archiving—and to compare EA with traditional paper-based examinations. The comparison focuses on time expenditure, costs, and acceptance among stakeholders.

The debate about EA compared to traditional paper exams is a central topic in current educational research. Questions of validity, reliability, and fairness play a crucial role [14]–[17]. Digitalization has brought about profound changes not only in business and administration, but also in education [18]–[22]. EA are part of this transformation and promise more efficient, flexible, and scalable assessment processes [23], [24]. Despite these advantages, the implementation of digital assessment formats requires strategic and cultural adaptations by educational institutions [25]–[28]. EA has evolved significantly in recent decades, evolving from simple online tests to complex systems capable of administering and scoring multimedia assessments [7].

The origins of EA date back to the early introduction of computer-based testing in standardized exams [29], [30]. With technological advances, universities began to explore the use of EA as a way to improve the assessment process, particularly with regard to scalability and accessibility [31]. Traditional exams are still considered the standard, primarily due to their established security mechanisms and students' familiarity with the format [32]–[35]. However, empirical studies show that paper exams are not necessarily more objective than digital formats. Hattie and Timperley [31] showed that formative EA with individualized feedback lead to better learning progress than summative paper exams. Archer *et al.* [32] point out that digital formats simplify administrative processes, while Gkrimpizi *et al.* [22] emphasize that digitalization alone does not solve organizational problems.

As already mentioned regarding the current state of knowledge, previous studies primarily demonstrate assumptions about efficiency gains through EA compared to conventional written exams [36]–[38]. These assumptions are supported by surveys of students taking exams. Statements primarily relate to quality gains (multimedia added value, typing instead of writing) [39]. EA offers numerous advantages over traditional exams. From an efficiency perspective, it reduces the time and cost required for printing, distributing, and grading exams. Furthermore, EA enables the integration of multimedia content, thus enabling a more comprehensive assessment of higher-level competencies. Students report that typing is easier than writing by hand and appreciate the ability to easily edit their answers without having to cross out mistakes [40]–[43]. EA offer a wide range of opportunities to improve exam quality. Jordan [40] emphasizes that adaptive testing procedures and automated feedback mechanisms enable more sophisticated performance assessment. Crisp [41] further argues that interactive elements in EA can address higher cognitive abilities, which is often not the case with MC tests. Study by Zhou *et al.* [42] show that EA can promote individualized learning processes. However, Majchrzak and Usener [43] note that while students generally support EA, they are skeptical about mandatory digital exams. The increasing use of artificial intelligence (AI) and learning analytics in performance assessment offers new opportunities for individualizing the learning process [44]. At the same time, there is still a need to further research digital assessment formats with regard to their fairness and psychometric quality [16], [45]–[47].

In summary, EA represent a valuable complement or even an alternative to traditional paper-based exams, provided the technical and didactic challenges are adequately addressed. Particularly important are the integration of feedback mechanisms [48], adaptation to specific subject areas, and the design of interactive elements [49], [50].

2. METHOD

In higher education research, efficiency is understood as the ratio of output to input. In relation to examinations, this means the more qualitative and quantitative results achieved with a given resource input, the more efficient the system. This approach can refer to both economic indicators (e.g., time expenditure, personnel requirements, and costs) and qualitative factors (e.g., satisfaction, fairness, and practicality). This study follows the process costing model, which has rarely been systematically applied in educational research. The mentioned model was used to collect process costs. This differentiates between the phases of preparation, implementation, evaluation, and archiving and records the time, personnel resources, and infrastructure costs spent in each phase. In addition, all audit steps were documented, time logs were maintained, and standardized effort forms were completed. The goal is to create a comprehensive picture of the efficiency differences between EA and PPE by recording all relevant effort throughout the audit process.

The empirical study is based on a mixed-methods design [50]. In three modules with different group sizes (Module A, n=33; Module B, n=489; Module C, n=194), identical examinations were administered in two different formats: traditional PPE and digital EA. The examination content, grading scheme, and duration were identical. The EA group used the Safe Exam Browser (SEB) in combination with Moodle. The PPE group wrote on paper in proctoring rooms. Even though the sample for this study refers to undergraduate degree programs, the transfer of findings to academic continuing education is justified: part-time students have comparable requirements for transparent, efficient, and flexible examination formats. Furthermore, universities are increasingly pursuing a cross-institutional digitalization strategy that encompasses all study formats.

The population of this study comprises undergraduate students enrolled in business-related degree programs at the ZHAW, Switzerland. The empirical data were collected within three regular course modules offered by the School of Management and Law, covering business administration and business engineering contexts. The sample was selected using a purposive sampling strategy, based on modules in which both traditional PPE and EA could be implemented under comparable conditions. Inclusion criteria were: i) identical examination content and grading schemes across formats; ii) comparable examination duration; and iii) feasibility of administering both MC and OQ formats digitally and on paper. In total, data from over 700 students were analyzed across three modules (Module A: n=33; Module B: n=489; Module C: n=194). Additionally to student data, respondents also included lecturers and examination administrators involved in the planning, implementation, grading, and archiving of the exams. This allowed the study to capture process-related time and cost data across all phases of the examination lifecycle. The respondents were therefore drawn from the field of higher education, specifically from business and economics education within a university of applied sciences context.

In addition to the process cost survey, a guided expert interview was conducted with Tobias Halbherr (personal communication, September 2023), Swiss Federal Institute of Technology – Educational Development and Technology (ETH-LET). The analysis was conducted using the qualitative content analysis method [21]. In addition, over 700 students answered a standardized questionnaire with Likert scales and open questions regarding their perception of the examination format, fairness, user-friendliness, and technology, in terms of satisfaction and practicability.

All cost figures in this study are reported in the currency Swiss Francs (CHF), as the empirical data were collected within the institutional and regulatory context of Switzerland. For international readability, CHF values may be interpreted as approximately equivalent to US dollars (USD) on a 1:1 basis. This approximation is used solely for interpretative purposes and does not affect the relative cost comparisons or efficiency ratios presented in the analysis. Since the study focuses on process efficiency and proportional differences, rather than absolute monetary values, the analytical validity of the results remains unchanged.

This analysis follows a process-oriented cost model, differentiating between the phases of preparation, implementation, evaluation, and archiving to provide a comprehensive overview of resource expenditure. The initial phase is characterized by significant personnel involvement from academic staff. The fiscal and temporal expenditure for the examination development is comprised of three primary phases: item construction, quality assurance, and technical integration. Item construction for the seven assessment tasks required one hour per task at a rate of CHF 100/h, totaling CHF 700. To ensure pedagogical rigor, quality assurance via peer-feedback and senior lecturer review (CHF 100/h) added 0.5 hours per task, amounting to CHF 350. Finally, the technical setup for digital implementation—including installation and demonstration

lessons—demanded 0.75 hours of coordinated effort between module leads (CHF 100/h) and technical support (CHF 80/h) per class.

The infrastructure follows a logic of amortization and institutional allocation. During the exam, costs are driven by logistical and supervisory personnel. Operational costs for hardware and basic infrastructure are calculated based on equipment lifespan and frequency of use, with emergency replacement devices and backup units totaling an allocation of CHF 30 per implementation, supplemented by a marginal cost of CHF 0.36 for essential peripherals like power strips. Software licensing for the SEB is distributed institution-wide, resulting in a per-participant cost of CHF 1.73 based on a cohort of 14,462 students. Logistical and on-site support includes student service provisions for paper-based requirements—calculated at CHF 0.05 per page plus a CHF 50/h supervision fee—as well as real-time technical assistance (CHF 80/h) and module lead oversight (CHF 100/h) to ensure examination stability.

In the post-examination phase, grading and archiving the efficiency depends heavily on the chosen exam format (MC vs. OQ). Grading and archiving represent the final significant resource expenditures, with the manual correction of OQ identified as the primary cost driver. This task requires approximately 0.5 hours per exam, totaling 17 hours of labor or CHF 1,700 for a standard cohort of 33 students. Furthermore, archiving procedures differ substantially by format; physical archiving (including scanning and logging) necessitates 5 minutes of administrative effort per exam, amounting to CHF 138. In contrast, digital formats facilitate automated archiving, effectively eliminating these manual processing costs and offering a more scalable alternative for larger student cohorts.

3. RESULTS AND DISCUSSION

The study comprised three field studies in different modules at the ZHAW, each with varying group sizes: Module A (n=33), Module B (n=489), and Module C (n=194). The three modules differ primarily in cohort size and organizational context, rather than in subject matter. All modules belong to the same academic field, namely business and economics–related programs at the ZHAW. The learning objectives, assessment standards, and institutional examination regulations were comparable across modules. The main difference lies in the number of respondents (n). The differing sample sizes therefore reflect naturally occurring cohort sizes, not selective sampling or differences in discipline. The modules were intentionally included to examine whether process efficiency effects scale with participant numbers. This design allows for comparing examination formats across small, medium, and large cohorts within the same field of study, thereby strengthening the robustness and transferability of the findings.

In each case, the exams were conducted in two parallel formats: as a traditional paper-pen exam and as an electronic EA. The entire exam process was analyzed from a process-economic perspective, including the phases of preparation, implementation, evaluation, and archiving. The results of the process cost analysis show clear efficiency advantages for the digital format. While the effort for both formats was comparable during the preparation phase, significant differences become apparent starting in the implementation phase: the PPE format required room booking, material logistics, and supervisory staff, among other things. These are partially or completely eliminated in the EA. The difference is most evident in the marking phase: automated evaluations made it possible to save up to 90% of the effort for EA, as seen in Table 1. For MC exams, EA provided major efficiency benefits. As shown in Table 2, in Module B (n=489), costs dropped from CHF 29,295 (PPE) to CHF 4,422 (EA), an 85% reduction. Similar patterns were observed in Module A and Module C, compare Tables 1 and 3. In contrast, for OQ formats, the cost savings were significantly reduced. While some process steps remained efficient (e.g., digital archiving, logistical setup), the manual grading required in EA offset most advantages. In Module B, the total cost for OQ EA was CHF 28,922, nearly identical to CHF 29,295 for PPE, as Table 2 indicates.

During the preparation phase, the effort was similar for both formats – although additional IT coordination was required for EA. During implementation, the logistical effort for printing, material distribution, room booking, and supervisory staff was significantly reduced for EA. The greatest difference became apparent in the marking phase: for closed question types, the marking effort for EA was practically eliminated. PPE required several hours of manual marking per exam. In archiving, PPE incurred costs for scanning processes, archiving storage, and data protection-compliant storage. EA automatically stores data digitally. In the largest field trial (n=489), total costs for EA were reduced by approximately 85% compared to PPE, compare Table 2. The detailed cost analysis shows that the savings potential of the EA had varying effects in all three modules.

The differences in efficiency depend largely on group size and organizational infrastructure. In Module A (n=33), the total process costs for PPE were approximately CHF 3,200, while for EA they were CHF 1,400 – a saving of approximately 44%, as seen in Table 1. The comparatively smaller difference is due, among other things, to the fact that for small groups, the costs for supervision and preparation can only

be reduced to a limited extent, even in a digital format. Table 1 provides a compact fourfold cost comparison (in CHF) between PPE and EA formats, each subdivided by MC and OQ types.

Table 1. Exam-costs-analysis dept. A ZHAW (MC-format and OQ-format; n=33)

Exam development and planning	P-P-E (MC)	E-A (MC)	P-P-E (OQ)	E-A (OQ)
Developing tasks	700	700	700	700
Internal quality control	350	350	350	350
Printing & staff	67	0	67	0
SEB & tech support	0	135	0	135
Subtotal	1117	1185	1117	1185
Exam implementation				
Replacement equipment	0	6	0	6
Power outlets	0	4	0	4
Software license (SEB)	0	13.5	0	13.5
Support-work	0	80	0	80
Exam-supervision	100	100	100	100
Subtotal	100	203.5	100	203.5
Exam grading				
Incoming controls	100	0	100	0
Examination correction	1700	0	1700	1700
Subtotal	1800	0	1800	1700
Exam archiving				
Scanning tasks	138	0	138	0
Subtotal	138	0	138	0
Total	3155	1388.5	3155	3088.5

Module B (n=489) yielded the most significant savings. PPE-related process costs totaled approximately CHF 29,300, while the EA variant was estimated at only CHF 4,400 – a reduction of almost 85%, compare to Table 2. Massive time and personnel savings were achieved, particularly in the implementation and correction phases. In Module C (n=194), PPE costs were approximately CHF 13,000 compared to CHF 2,500 for EA. In addition, assessment costs dominated the savings potential, as Table 3 shows, the automatic correction of over 90% of tasks reduced processing time to a minimum.

Table 2. Exam-costs-analysis dept. T ZHAW (MC-format and OQ-format; n=489)

Exam development and planning	P-P-E (MC)	E-A (MC)	P-P-E (OQ)	E-A (OQ)
Developing tasks	700	700	700	700
Internal quality control	350	350	350	350
Printing & staff	495	0	495	0
SEB & tech support	0	1350	0	1350
Subtotal	1545	2400	1545	2400
Exam implementation				
Replacement equipment	0	200	0	200
Power outlets	0	9	0	9
Software license (SEB)	0	13.15	0	13.15
Support-work	0	800	0	800
Exam-supervision	1000	1000	1000	1000
Subtotal	1000	2022.15	1000	2022.15
Exam grading				
Incoming controls	200	0	200	0
Examination correction	24500	0	24500	24500
Subtotal	24700	0	24700	0
Exam archiving				
Scanning tasks	2050	0	2050	0
Subtotal	2050	0	2050	0
Total	29295	4422.15	29295	28922.15

3.1. Phase-related efficiency gains

The present results clearly demonstrate that electronic examinations are not only an innovative but also an extremely efficient tool for assessing performance, as seen in Tables 4-6. Advantages emerge on several levels: i) personnel and organizational effort are significantly reduced; ii) students benefit from faster feedback, greater transparency, and less stress. The results of the study underscore the assumption that EA enable significant efficiency gains throughout the entire examination process compared to traditional paper-based examinations (Tables 1-3). Automated evaluation and archiving, in particular, led to a drastic reduction

in personnel and logistical effort. Compared to traditional paper-based examinations, the effort is reduced by up to 90%. These findings are consistent with existing studies, which emphasize automation as a key potential of digital examination formats [51], compare to Table 4.

Table 3. Exam-costs-analysis dept. W ZHAW (MC-format and OQ-format; n=194)

Exam development and planning	P-P-E (MC)	E-A (MC)	P-P-E (OQ)	E-A (OQ)
Developing tasks	700	700	700	700
Internal quality control	350	350	350	350
Printing & staff	245	0	245	0
SEB & tech support	0	675	0	675
Subtotal	1295	1725	1295	1725
Exam implementation				
Replacement equipment	0	40	0	40
Power outlets	0	2	0	2
Software license (SEB)	0	14.5	0	14.5
Support-work	0	320	0	320
Exam-supervision	400	400	400	400
Subtotal	400	776.5	400	776.5
Exam grading				
Incoming controls	300	0	300	0
Examination correction	9500	0	9500	9500
Subtotal	9800	0	9800	9500
Exam archiving				
Scanning tasks	800	0	800	0
Subtotal	800	0	800	0
Total	12295	2501.5	12295	12001.5

Table 4. Total exam costs by format and module (in CHF)

Module	PPE MC	EA MC	%Δ	PPE OQ	EA OQ	%Δ
A (n=33)	3,155	1,388.50	-56	3,155	3,088.50	-2.1
B (n=489)	29,295	4,422.15	-84.9	29,295	28,922.15	-1.3
C (n=194)	12,295	2,501.50	-79.7	12,295	12,001.50	-2.4

As shown in Tables 5-7, the preparation phase showed only minor differences between PPE and EA across all three modules. In Module B, digital organization (e.g., exam settings in Moodle, import of student numbers) resulted in a time saving of 20–25%. However, the greatest impact was seen in the implementation: while PPE requires numerous analog processes (printouts, materials, scanning, and archiving), EA was able to largely replace these with software-supported management and control functions. The effect was particularly strong in the assessment phase. For example, Table 2 shows PPE correction in Module B required over 120 hours (estimated cost: CHF 10,800), whereas EA corrections were completed in under 10 hours (CHF 950). A similar pattern emerged across all modules. The archiving phase for PPE was characterized by scanning, logging, and storage. EA data, on the other hand, was stored automatically on a server—with clear advantages in terms of data protection, access security, and long-term availability. The analysis clearly shows the larger the exam group and the more standardized the format, the greater the efficiency benefits of EA, as shown in Tables 5-7.

Table 5. Cost breakdown by process phase (in CHF) – Module A (n=33)

Phase	PPE MC	EA MC	%Δ	PPE OQ	EA OQ	%Δ
Preparation	1,117	1,185	+6.1	1,117	1,185	+6.1
Implementation	100	203.50	+103.5	100	203.50	+103.5
Grading	1,800	0	-100	1,800	1,700	-5.6
Archiving	138	0	-100	138	0	-100
Total	3,155	1,388.50	-56	3,155	3,088.50	-2.1

Table 6. Cost breakdown by process phase (in CHF) – Module B (n=489)

Phase	PPE MC	EA MC	%Δ	PPE OQ	EA OQ	%Δ
Preparation	1,545	2,400	+55.3	1,545	2,400	+55.3
Implementation	1,000	2,022.15	+102.2	1,000	2,022.15	+102.2
Grading	24,700	0	-100	24,700	24,500	-0.8
Archiving	2,050	0	-100	2,050	0	-100
Total	29,295	4,422.15	-84.9	29,295	28,922.15	-1.3

Table 7. Cost breakdown by process phase (in CHF) – Module C (n=194)

Phase	PPE MC	EA MC	%Δ	PPE OQ	EA OQ	%Δ
Preparation	1,295	1,725	+33.2	1,295	1,725	+33.2
Implementation	400	776.50	+94.1	400	776.50	+94.1
Grading	9,800	0	-100	9,800	9,500	-3.1
Archiving	800	0	-100	800	0	-100
Total	12,295	2,501.50	-79.7	12,295	12,001.50	-2.4

Tables 5-7 show that while EA MC formats generate substantial cost savings, EA OQ formats remain almost as costly as their PPE counterparts due to the manual grading burden. Figure 1 isolates the total costs of MC exams across all three modules, comparing paper-based and electronic assessment formats. The cost advantage of EA is immediately evident. In Module A, costs dropped from CHF 3,155 to CHF 1,388.50 (−56%), while Module B, with its larger cohort, saw a reduction from CHF 29,295 to CHF 4,422.15 (−84.9%). Similarly, Module C demonstrated a cost saving of nearly 80%. These findings reaffirm the scalability and economic efficiency of digital MC examinations, especially in settings with high participant numbers and standardized testing structures, as seen in Figure 1.

Figure 2 illustrates the relative cost savings for each module and exam format. The efficiency gains of MC EA are substantial and consistent, with savings exceeding 75% in all cases. Conversely, OQ EA show only minimal reductions. The graph underscores the central role of automation in realizing efficiency, revealing a strong correlation between question format and cost impact.

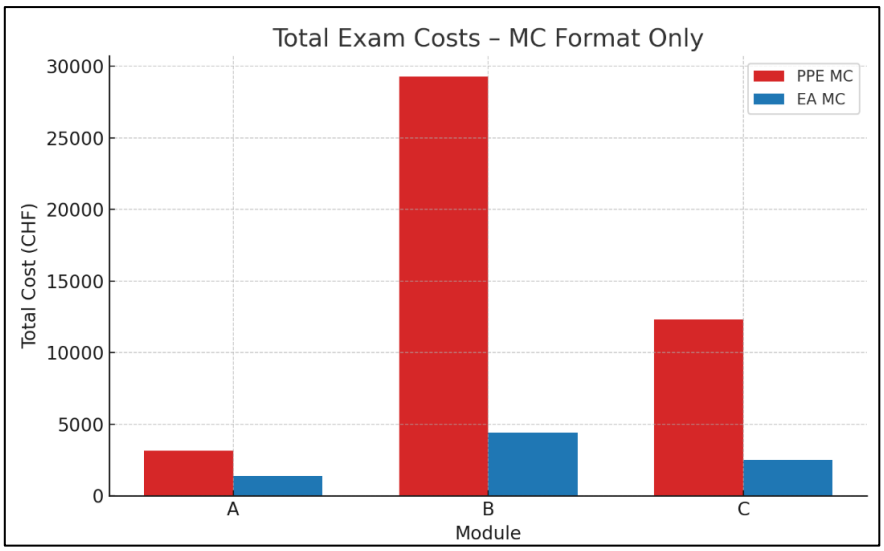

Figure 1. Total exam costs-MC format only

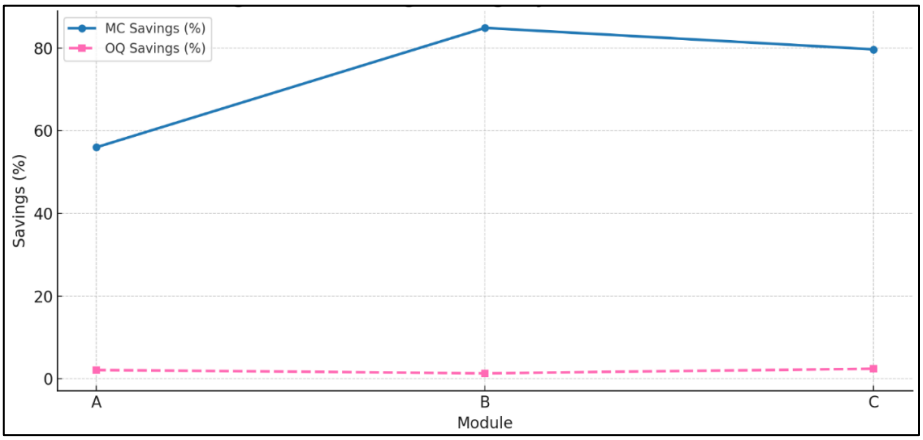

Figure 2. Percentage savings by format and module

Figure 3 compares the total examination costs for both MC and OQ formats across Modules A, B, and C. The data clearly demonstrate substantial savings for EA in MC settings, particularly in large-scale exams such as Module B. While traditional MC and OQ exams consistently incurred identical costs, digital MC formats achieved cost reductions between 56% and 85%. In contrast, digital OQ formats yielded only marginal savings (1–3%), confirming that manual grading continues to drive cost parity with paper-based exams.

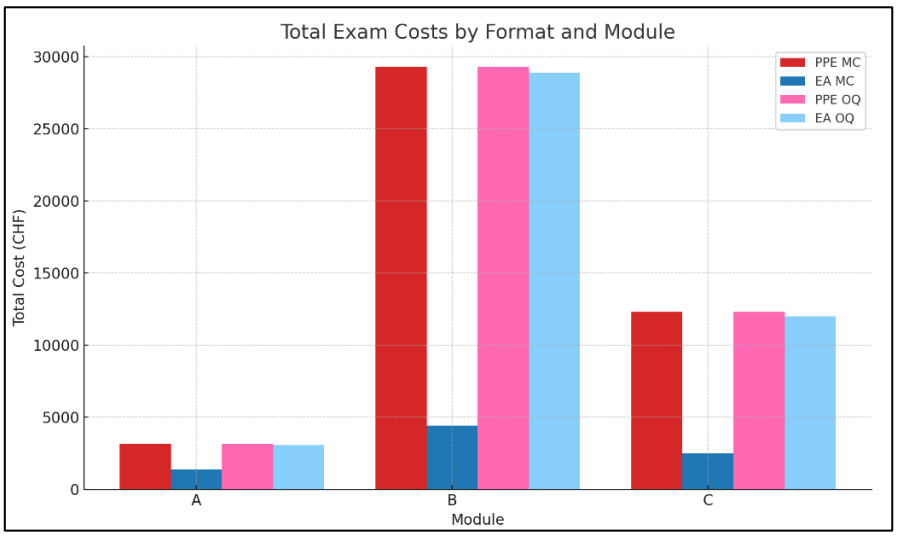

Figure 3. Total exam costs by format and module

Figure 4 breaks down the cost savings by process phase (preparation, implementation, grading, and archiving) for MC exams in all three modules. The most pronounced reductions occur in the grading and archiving phases, each reaching 100% due to full automation. In contrast, the implementation phase shows notable cost increases—exceeding 90% in all modules—attributable to digital infrastructure, monitoring, and SEB configuration. Preparation phase costs also increased slightly, especially in larger modules.

Figure 5 presents the phase-specific cost differences for OQ exams. While archiving savings remain consistent at 100%, grading is only slightly more efficient due to continued reliance on manual correction. Implementation and preparation phases exhibit cost increases of 30–100%, similar to those observed in MC settings. These results indicate that without automation in grading, the economic potential of digital OQ formats remains largely untapped.

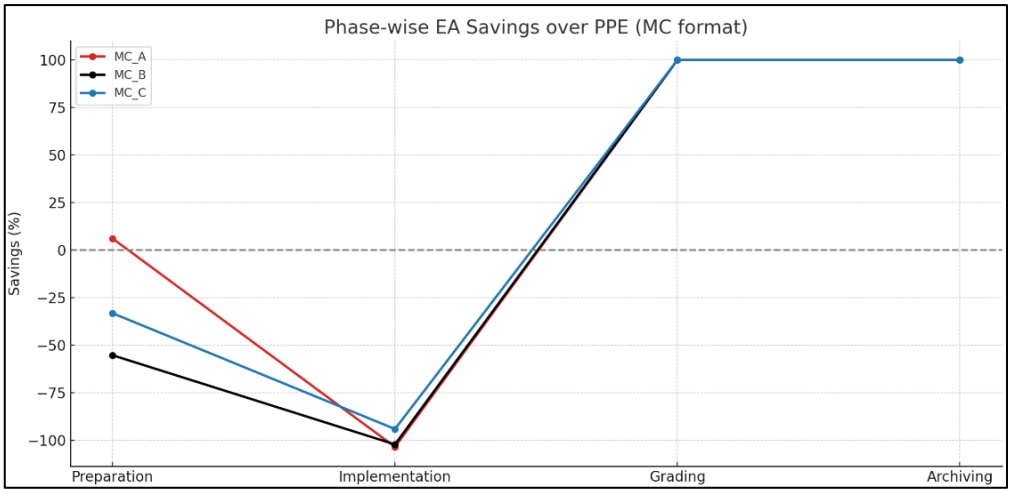

Figure 4. Phase-wise EA savings over PPE (MC-format)

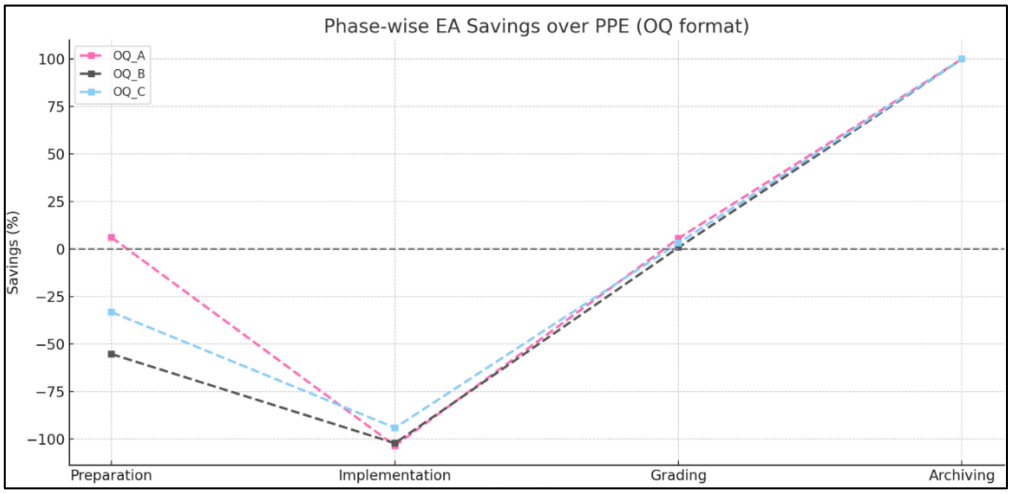

Figure 5. Phase-wise EA savings over PPE (OQ-format)

At the same time, qualitative data from interviews and student surveys confirm the high level of acceptance and satisfaction with the digital exam formats. To assess students' perceptions of the examination formats, a standardized questionnaire was administered after the examinations. The instrument measured key variables related to satisfaction, perceived fairness, practicality, and user-friendliness of the examination format, as well as attitudes toward the underlying technology. Each construct was operationalized using multiple items rated on a 5-point Likert scale ranging from strongly disagree to strongly agree. Perception of the examination format captured students' overall evaluation and preference for digital versus paper-based exams. Fairness items focused on perceived equality of conditions, transparency of grading, and absence of disadvantage due to the exam format. User-friendliness and practicality were measured through items addressing ease of use, clarity of navigation, time handling, and perceived workload. Technology-related items assessed system reliability, technical stability, and confidence in handling the digital examination environment. In addition, open-ended questions allowed respondents to provide qualitative comments and highlight advantages or concerns related to the examination format.

The qualitative results also paint a consistent picture. Students predominantly rate EA positively, especially in terms of user-friendliness (84%) and fairness (77%). The student survey reveals a predominantly positive attitude: 76% prefer digital exams, 83% found the assessment to be fair, and 92% support the use of EA in additional modules. Dealing with technical problems was cited as a critical issue – albeit only by a small proportion (9%). The high level of acceptance among students is particularly noteworthy. It shows that digital assessments are not only feasible but also desirable – provided transparency, technical stability, and preparation are guaranteed. The high level of agreement with the perception of fairness, in particular, indicates that EA formats do not create discrimination, but are, on the contrary, experienced as equal opportunities. While many emphasize advantages such as transparency, structure, and fairness, concerns about technical glitches remain. The introduction of a backup concept, e.g., through mobile devices or alternative access, is therefore strongly recommended. Overall, however, the willingness to use digital assessments is very high, provided the process is clearly communicated and supported by practice formats.

The qualitative interview with Tobias Halbherr shows that the successful use of EA is not just a technical issue, but requires profound didactic and organizational change. Acceptance among teachers is dependent on training, time resources, and support structures. The results suggest that simply digitizing the format—without accompanying measures—does not automatically lead to gains in quality or efficiency. This finding aligns with research indicating that e-assessments are part of a comprehensive paradigm shift in higher education assessment [22], [52].

4. CONCLUSION

This study contributes to the literature on digital assessment by providing an empirical cost analysis of e-assessments compared with traditional paper-based exams. The findings show that the economic benefits of digital examinations depend strongly on the assessment format. MC e-assessments lead to substantial cost reductions—up to 85% in high-volume modules—primarily due to automated grading and digital archiving. In contrast, OQ formats show only marginal cost advantages because grading remains largely manual.

These results suggest that universities seeking scalable and cost-efficient assessment processes should prioritize MC-based e-assessments in standardized, high-enrollment courses. At the same time, successful implementation requires reliable technical infrastructure, institutional strategies, and adequate training for teaching staff. Future technological developments, particularly AI-assisted scoring systems, may further increase the efficiency of digital assessments involving open responses. The study is limited to business and economics modules at a Swiss university and focuses primarily on quantifiable efficiency indicators. Future research should examine other disciplines and explore long-term developments in efficiency, acceptance, and assessment quality as digital examination systems continue to evolve.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Flavio Di Giusto	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Author states no conflict of interest.

DATA AVAILABILITY

The data that supports the findings of this study are available from the corresponding author, [FDG], upon reasonable request.

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