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PAPER

Maximizing Learning Outcomes while Minimizing Costs: A Cost-Effective Approach to M-Learning

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ABSTRACT

In the realm of education, the pursuit of effective learning outcomes often faces the challenge of limited resources. This paper explores the intersection of maximizing learning outcomes and minimizing costs through a cost-effective approach to mobile learning (m-learning). Recognizing the ubiquitous presence of mobile devices and their potential to revolutionize learning, this study explores strategies that leverage the capabilities of mobile technology while being mindful of budgetary constraints. By leveraging the flexibility and accessibility offered by m-learning platforms, educators can design engaging and interactive learning experiences that cater to diverse learners needs. The paper investigates various cost-effective methodologies, including utilizing open-source software, repurposing existing resources, and adopting collaborative learning environments. Furthermore, it examines the role of scalable technologies and adaptive learning algorithms in optimizing resource allocation and personalizing learning experiences. Through case studies and empirical analysis, this research illustrates how institutions and educators can achieve significant cost savings without compromising the quality of educational delivery. Ultimately, the findings highlight the transformative potential of a cost-effective approach to m-learning in enhancing learning outcomes and widening access to education.

KEYWORDS

mobile learning (m-learning), cost-effectiveness, mobile technology, resource optimization, learning outcomes

1 INTRODUCTION

In recent years, various approaches to traditional education have been introduced, incorporating the latest advancements in information and communication technologies. These include virtual libraries and multimedia centers for individuals looking to enhance their cultural knowledge on demand, as well as e-education or distance education for students unable to attend regular classes due to their

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schedules or locations. The impact that mobile phones, the web, and cutting-edge technology have had on our daily routines, lifestyles, businesses, shopping habits, communication styles, and leisure activities is no longer news.

The alternatives to traditional education offer speed, flexibility, and creativity.

This paper explores whether the majority of students' lives and education are significantly impacted by their ability to access and create new information through mobile devices. The report also examines the performance of this type of computer application. A handheld device is a single, consolidated point of contact that provides users and students with convenient access to applications, data, and information. Mobile devices simplify data transfers. By enabling the creation of complex geometries that are impractical or prohibitively expensive to build using conventional manufacturing techniques, metal additive manufacturing (MAM) has the potential to provide unprecedented levels of design flexibility. Additionally, it is making it possible to produce parts that are substantially lighter while maintaining the same level of performance. This advancement might have a positive impact on the environment and the economy in various industries, such as aviation, healthcare, and the energy sector. However, many manufacturing sectors are unable to widely adopt MAM due to its relatively high production costs.

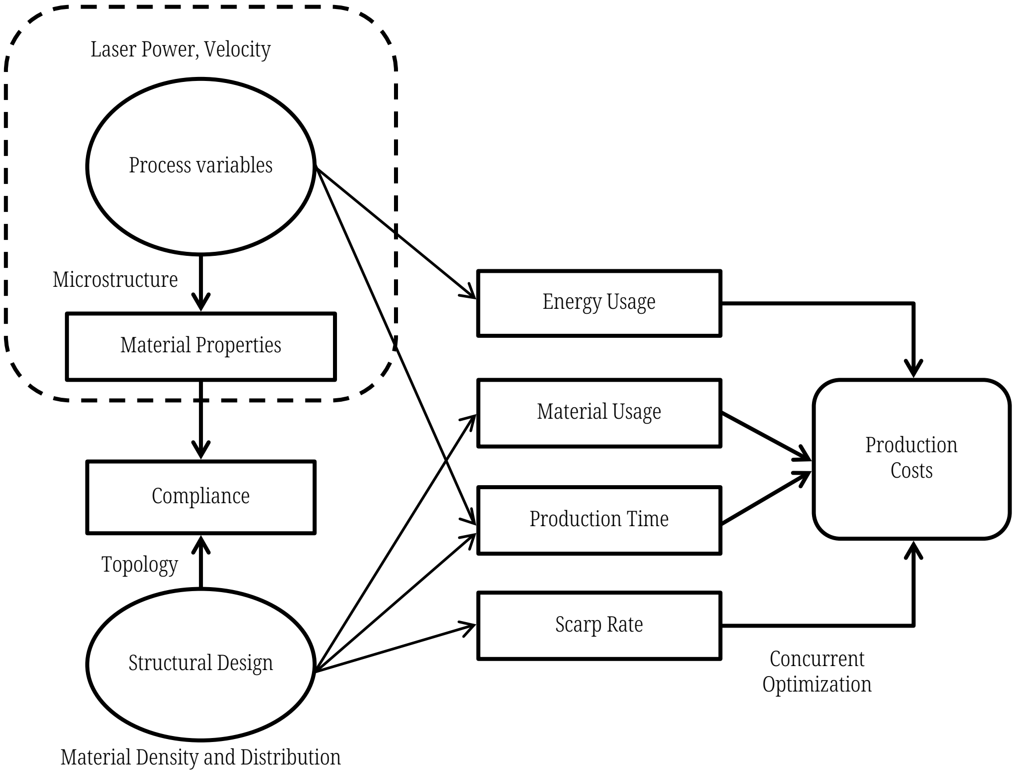

Fig. 1. Framework for cost minimization (The aspects included in the concurrent optimization are shown by the dashed lines; the structural design optimization alone is not covered)

Research has shown that optimizing the skeletal layout of MAM parts can help reduce material utilization and, consequently, material costs while retaining component performance. As a substitute for material costs, the traditional topology optimization formulation minimizes conformance or stress while considering a constraint on the total volume. The topology of a part, however, affects production costs in ways other than those related to the materials used in making the finished product.

For instance, the precise location of material additions and removals from a part within the machine build environment affects scrap and energy expenses.

In addition, MAM process variables such as laser power and speed affect material qualities and manufacturing expenses associated with machine energy and time. Therefore, there may be additional manufacturing cost savings by concurrently optimizing both the MAM procedure variables and a part's topology [2]. There is prior literature discussing the possibility of optimizing AM process parameters and part structure, as well as empirical case studies presenting process parameter optimization within a fixed topology. However, no prior literature has simultaneously optimized both a part's structure and process factors. Furthermore, as we will demonstrate, there are currently no defined approaches to minimizing total manufacturing expenses in topology optimization. This can lead to part designs that deviate significantly from the conventional approach typically employed in topology optimization. In this study, we present a production cost minimization strategy for MAM that simultaneously optimizes process factors such as laser power and velocity and component structure (see Figure 1). Process-based cost modeling (PBCM), efficient topology optimization, and MAM processes and solidification mapping are integrated to establish the methodology linking process parameters and structure.

Large-scale social or institutional use and commercial exploitation must come next if these projects prove to be educationally and technically effective, serving as the focal point for a consensus on what [3] truly constitutes mobile learning (m-learning). This may incorporate publicly sponsored support within government programs and ongoing provision rather than necessarily taking the form of direct free-market commercialization.

This paper's later sections delve into a comprehensive investigation. A comprehensive review of the literature is presented in Section 2, focusing on relevant studies and contemporary frameworks in the field. The approach utilized in our study is presented in Section 3, which also describes the simulation methods and mathematical models that were applied to reliability analysis. The findings of our simulations and assessments are presented in detail in Section 4, which also offers insights into how dynamic scenarios impact the reliability of data transmission. Section 5 summarizes the paper's major conclusions and highlights the research's greater significance in improving the field of mobile collaboration.

2 LITERATURE REVIEW

An m-learning service provider is an organization that offers electronic learning services. Its functions include managing users [4], providing access services, and ensuring user satisfaction. It describes a generic architecture that extends the components of an existing LMS to enable the deployment of m- and e-learning applications. This architecture may have specifics particular to the supported services and technologies. Additionally, it discusses an agent-based system within the context of m-learning environments. Future research on this challenge will focus on examining an actual m-learning architecture, as it requires a real m-learning platform.

Furthermore, the global emergency has made m-learning even more popular. The global education system has undergone a complete transformation due to the COVID-19 outbreak. Many organizations [5], colleges, universities, and institutions have ceased face-to-face training. They are now compelled to go online to pursue their teaching aspirations. This will negatively impact educational activities because social distancing must be observed during this time. Organizations that had previously been reluctant to adapt and use m-learning have been compelled to do so by this situation. For educational institutions, coping with the existing situation has been and continues to be challenging, especially in the field of science and technology instruction.

Students can "leave" the classroom and participate in activities that do not follow the curriculum or the teacher's agenda when they can connect to activities in the outside world. Mobile devices' "anytime, anywhere" features promote learning outside of a classroom setting under the supervision of a teacher [6]. The two situations pose serious obstacles to traditional teaching methods. If students believe that their social networks are under attack, they may cease using certain tools. The advantages of the informality of mobile devices could be lost if their use in classrooms becomes widespread. For instance, a team of researchers provided 600 students with cell phones to examine if they used them for non-learning purposes at night.

Initially, it entails a technologically advanced learning environment that combines the virtual and mental realms. Secondly, it offers tools for computer technology, interaction support, and a variety of instructional and learning activities. Thirdly, it facilitates the collection, gathering, processing, and analysis of student information to optimize and maximize pedagogical judgments [7]. Fourthly, it provides students with access to an open learning environment where they can experience real classroom settings. Higher-order thinking skills have also been proven to benefit from the inclusion of mobile devices in the curriculum, according to research.

When creating regulations regarding online educational settings, legislators can greatly benefit from the current advancements in mobile learning, or m-learning. Consequently, conducting a systematic literature review (SLR) would be an advantageous strategy to fully comprehend the advancements made in the field of M-Learning so far and to guide future research [8]. To provide an overview of the current state of the field, identify gaps in research, and suggest directions for future exploration, SLR would systematically identify, evaluate, and synthesize existing studies. Decision-makers would be able to arrive at evidence-based policy choices with the help of this comprehensive approach, which would also ensure that future m-learning research addresses the gaps and advances virtual classrooms.

In light of the swift advancements in digital learning, it is imperative to further enhance our comprehension of cognitive load theory to align with the expanding corpus of research. In this article [9], we seek to advance the theory by incorporating relevant empirical findings to facilitate a more comprehensive understanding of cognitive burden. The theoretical underpinnings of cognitive load theory are briefly reviewed in this section, after which we provide a more thorough summary of the five issues that have already been raised. We have developed a new theoretical model based on this data, correlating different forms of mental processes with various types of cognitive burden.

3 METHODS AND MATERIALS

3.1 Optimizing effectiveness and reducing expenses

Determine the needs for training. Assessing the specific training requirements of your staff and company is crucial before initiating any training programs. To identify the skills and knowledge gaps that need to be addressed, a comprehensive analysis of training needs should be carried out [10]. If your customer service team finds it difficult to deal with challenging consumers, you can create a focused training program on conflict resolution and effective communication to specifically address this problem.

Make necessary training a priority. Not every training program is created equal. Prioritizing the essential training courses that align with the goals and objectives of your company is crucial. To save expenses and enhance the effectiveness of your training programs, focus on the most crucial topics. For example, if your company is transitioning to a completely new software system, funding training courses will be crucial to ensuring that the system is adopted smoothly and that users become proficient with it.

Employ e-learning and technologies. Customized training techniques can be expensive and time-consuming. Adopting e-learning platforms and technology can maximize efficiency while drastically lowering training costs. Employees can be provided with the option to learn at their own pace and convenience through webinars, simulated classrooms, and online training courses. Technology also simplifies the distribution of training materials to a geographically dispersed workforce, eliminating the necessity for travel and accommodation expenses associated with in-person instruction.

Utilize internal assets. Utilizing your organization's internal skills and knowledge is a cost-effective training strategy. Encourage experienced workers to mentor their peers and share their knowledge. This not only encourages a culture of ongoing education but also reduces the expense of hiring outside consultants or trainers. Moreover, establishing an internal wiki or knowledge-sharing platform can aid in the organization-wide dissemination of important data and guidelines.

Assess the efficacy of instruction. To ensure that your training efforts are yielding the intended outcomes, it is crucial to assess their efficacy [11]. You can identify areas that require improvement and make necessary changes by evaluating the impact of training programs on employee performance and organizational goals. Productivity metrics, staff surveys, and pre- and post-training assessments can all be used to achieve this goal. Analyzing sales results before and after an advertising training program, for example, can provide insights into the program's effectiveness if its objective is to increase revenues.

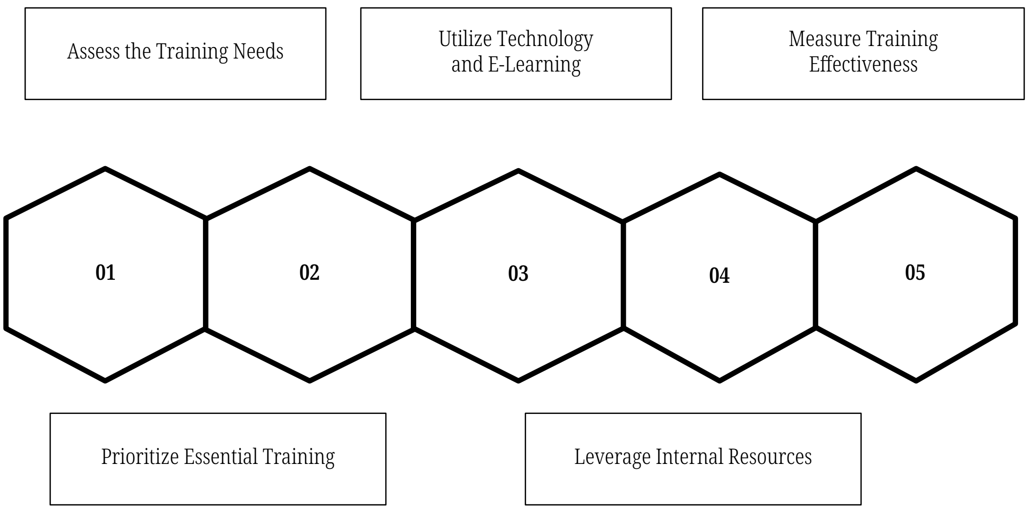

Fig. 2. Employee training: Increasing productivity and lowering costs investing sensibly: The contribution of staff training to cost saving

3.2 Classification

Due to the intense nature of data, multimedia applications, such as m-learning applications, address a variety of problems. We used an issue-based taxonomy to illustrate these technical concerns in Figure 3 [12], along with a brief explanation of the problems and their root causes.

Problems with mobile devices. The compact shape of mobile devices is the main reason for the limitations on mobile device components, as illustrated in Figure 3. As a result, there are fewer and potentially fewer resources available on mobile devices, including poor power consumption, preservation, input techniques, and smaller screens. The speed at which memory and CPU power are evolving is much faster than the current state of battery power. Multimedia content analysis and transmission rapidly deplete battery life. For multimedia delivery and processing in the mobile environment, energy-efficient algorithms and protocols must be designed due to the limited battery capacity. Another problem is device heterogeneity, caused by different operating systems and hardware designs. Additionally, there is a significant difference among mobile devices in terms of screen sizes, resolutions, and encoding and decoding methods. Therefore, it is imperative that the same multimedia material be optimized and transparently processed for consumers, considering the practical and structural features of handheld devices.

3.3 Networking problems

Figure 3 illustrates the dynamics of a wireless network that affect QoL and QoE [13], as well as the behavior of a multimedia-enabled m-learning application. The following is a brief description of these challegnges:

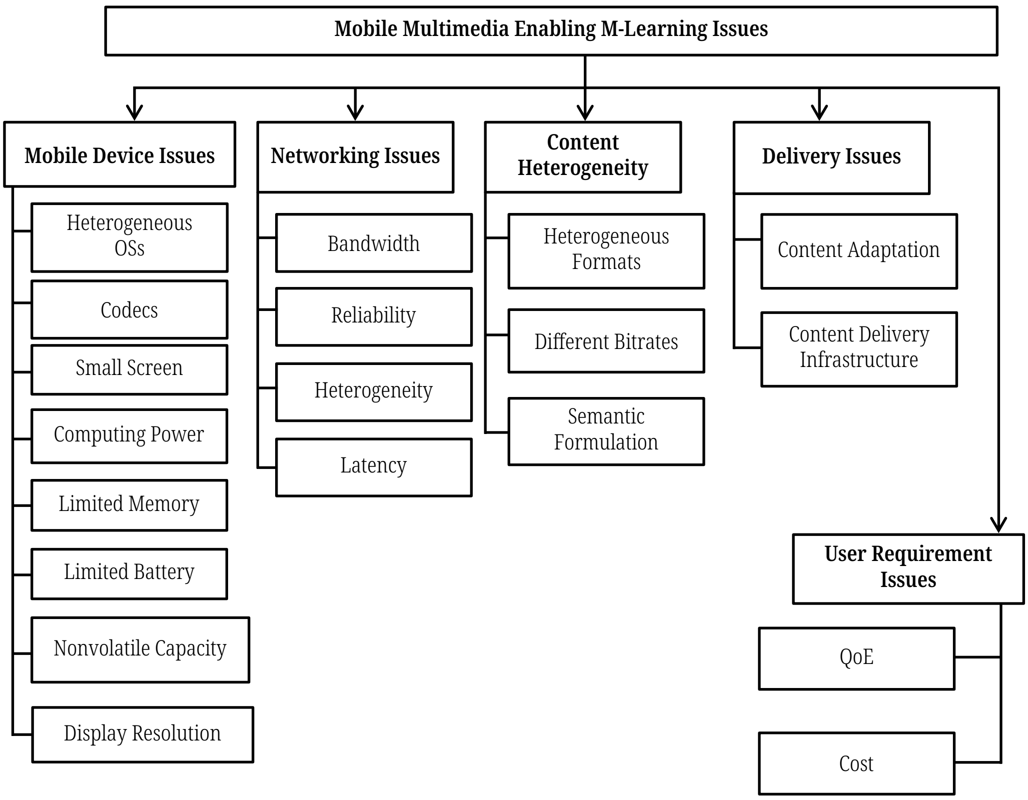

Fig. 3. Taxonomy of challenges with multimedia-enabled mobile learning

Limited bandwidth. Since the bandwidth available in wireless radio networks is much less than that in traditional networks, low bandwidth is one of the challenges that could adversely affect the quality of service (QoS) of any wireless multimedia applications. The complexity of the problem is further compounded by the variability in bandwidth caused by external factors such as weather. Hopefully, the forthcoming deployment of modern wireless networks will alleviate this limitation, but it will not be completely eliminated as the clip bit rate also increases steadily over time.

Network dependability. Given that the quality of experience of multimedia-enabled m-learning applications heavily depends on persistent network connectivity with tolerable packet loss, latency, and capacity, mobile network dependability is an urgent issue. Due to frequent flow bottlenecks and failures in wireless radio networks, a mobile learner's ability to connect to their educational provider may be hindered. Mobile learning depends on the access network. It might be challenging to offer a dependable, scalable, and cost-effective Wi-Fi connection for learners to use while traveling in locations such as subways and tunnels due to frequent disconnections.

Variability. Through any of the radio connections available on smart handheld devices, such as GPRS, Wi-Fi, WiMax, and LTE, users can access the multimedia-enabled learning platform. Installing an effective connection algorithm on the m-learning server and client structure is crucial in diverse network availability situations. This feature allows users to maintain a persistent connection and seamlessly switch established network connections between interfaces while remaining connected to the server-side educational system.

Elevated delay of access. One of the main challenges that mobile multimedia-enabled m-learning systems face is the longer network access delays in wireless radio systems. Extended delays and lost connections significantly impact the quality of life and learning experience of mobile learners [14]. People are sensitive to the degradation in quality caused by jitter and extended delays in WAN and mobile networks, which are very challenging to manage. On the other hand, modern access networks have significantly increased capacity, but improvements in latency are improbable.

4 IMPLEMENTATION AND EXPERIMENTAL RESULTS

This section aims to identify research gaps and propose new research topics on the subject of m-learning in higher education. The studies included in this analysis were classified using the TCCM structure as described by Paul and Rosado-Serrano. The TCCM framework, which focuses on four important dimensions—theory, context, characteristics, and methodology—offers a systematic approach to identify research gaps and guide new lines of inquiry. In contrast to other review styles, such as bibliometric or narrative reviews, Paul and Rosado-Serrano argue that theme-based assessments and framework-based reviews, like the TCCM framework, are more effective in identifying research gaps. This study is enhanced by the application of the TCCM framework, which enables an organized review of the research works.

Studies have shown that the TCCM framework is widely used in a variety of fields, including gamification and e-learning. Its broad range of applications across various fields attest to its effectiveness in guiding research investigations and identifying knowledge gaps. The TCCM framework's dimensions will all be covered in detail in the paragraphs that follow, providing insight into the goals and components of each dimension. By examining these aspects, scholars can gain a deeper understanding of the areas that require further investigation and study in the field of m-learning in educational institutions.

The geographic distribution of the literature and the demographics of the participants in the study—faculty, staff members in higher education, and students—have assisted in identifying the context. Figure 4 displays the categorization of research based on the country where the study was conducted. Comparing affluent countries (29.1%, 47 studies) with developing nations (70.8%, 114 studies) [15], it is evident that the majority of m-learning research is conducted in the former. Furthermore, the distribution of papers analyzed in the study by country is highlighted in Figure 4. The majority of published literature on m-learning is found to have been undertaken in Malaysia, Jordan, Taiwan, and China. Studies that failed to identify a specific geographic region are also present in the literature. However, due to the diverse and scattered nature of the research on this topic, reaching a definitive conclusion is challenging. The majority of m-learning research to date has focused on distance education in specific countries. This presents an opportunity to explore a broader array of topics and locations, providing study opportunities across various regions and countries.

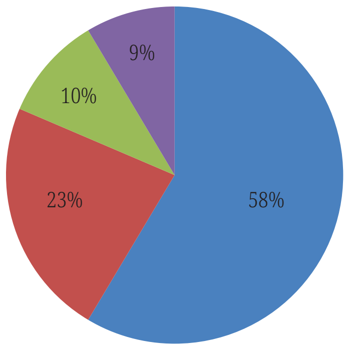

Fig. 4. Type of country: developing and developed

The studies that have been selected involve participants classified as students, staff, and faculty in higher education. The total number of studies categorized by population is illustrated in Figure 5. Studies involving students outnumber those involving instructors (5.0%, eight studies) and higher education executives (2.2%, two studies), accounting for 83.8% of the 251 studies. This is a direct result of the powerful impact of m-learning on student achievement and academic outcomes. Students are also more adept at using mobile applications for education and regularly use cell phones. Furthermore, due to COVID-19 regulations preventing them from attending schools or institutions, a large number of students are compelled to study via the internet from home using mobile devices.

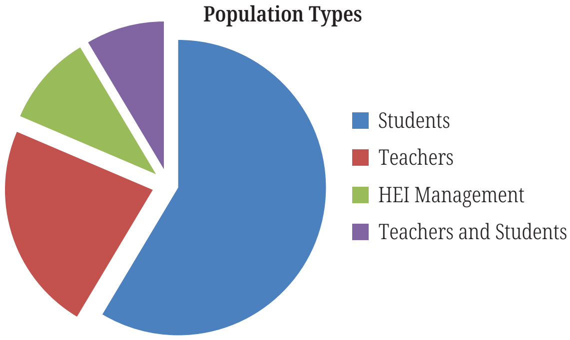

Fig. 5. The demographics of educators and learners

According to Figure 4, the most popular research design is quantitative research design (n = 165; 90%), followed by mixed methods research design (n = 22; 8%), and qualitative research design (n = 5; 3%). The most popular research methods in m-learning include surveys, descriptive analysis, correlational analysis, and regression analysis in the quantitative methods study design. The questionnaire was found to be the most widely used method by investigators in the field to ascertain users' reasons for choosing online learning as a medium for learning, as well as for understanding the utilization of mobile devices and Internet access methods. The awareness of utilizing mobile devices for m-learning, students' perspectives on using phones for education, learners' behavioral intentions, and knowledge sharing among learners.

Structural equation modeling is the most frequently used data analysis method in the m-learning literature. This methodology has been applied in studies that have required a significant volume of data from a large number of participants. On the other hand, focus groups, interviews, and systematic literature reviews are some of the research strategies used in the selected papers within the qualitative research methodology. To evaluate the accessibility, approval, and acceptance of m-learning, qualitative methods are applied. The research was conducted with instructors and students in mind. Nearly every researcher has formally collected participant demographic data, such as age, gender, race, year of study, degree program, and program. To address research concerns, several investigations require the application of various research approaches. Research design utilizing mixed methodologies has been employed in these investigations. Still, there isn't as much research on this topic.

5 CONCLUSION

The m-learning platforms revolutionize the learning process by integrating the power of computing and communication into the learning cycle, enabling access from any location and at any time. Several pedagogical and technological challenges make it challenging to design educational content (learning objects) for mobile devices and m-learning platforms. For learning to be seamless, these challenges need to be resolved.

The paper provides recommendations for researchers, both novice and expert, to enhance their m-learning studies based on these findings. Future studies are encouraged to focus on evaluating the added value of m-learning, exploring current or controversial educational topics that have received little attention, and employing comprehensive analysis techniques to assess learners' performance from multiple perspectives. This study identifies specific research needs in the field of m-learning related to relevant theories, contexts, features, and research methodologies. The results provide crucial guidance for scholars interested in advancing the topic of m-learning and help identify the areas that require further investigation.

The strategy presented in the paper is only a proof of concept, and further research needs to address several challenges. The cost model does not account for other life cycle stages, such as the cost savings associated with light weighting during the usage phase, and only analyzes the economic differences of the production stage. The design solutions may change as a result of considering complete life cycle costs. We intend to create models that consider the benefits of incorporating complete life cycle costing. Additionally, the method did not optimize the tool path, orientation, packaging, quantities produced, or batch size—all of which have a significant impact on production costs.

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