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**Master's Programme in Chemical, Biochemical and Materials Engineering**

# Assessment of learning in digital learning environments

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**Mariam Icar**

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**Abstract**

Digital learning (e-learning) has become transformative tool within both educational and corporate sectors. It provides benefits, such as self-paced learning, increased motivation, and cost-effectiveness. Despite these advantages, gaps still do exist in optimising learning outcomes and integrating generative artificial intelligence into educational settings. This thesis studies how ForestBioFacts as an example of a digital learning environment can address these gaps to improve learning effectiveness.

In this thesis, three research objectives were formulated. Firstly, examining the effects and successful implementation of learning outcomes. Secondly, assessing the impact of various question formats on learning. Thirdly, evaluating the role of generative artificial intelligence in enhancing the efficacy of digital learning environments. To fulfil the objectives, a quantitative approach including an online quiz and a post-questionnaire was employed.

The empirical study involved ten participants split into two groups. Group, which received learning outcomes and pre-materials achieved somewhat higher correct response rates compared to a group which only received pre-materials. These findings highlight the importance of well-defined learning outcomes in reducing cognitive load and increasing motivation. Furthermore, the research highlighted a preference for multiple-choice and true or false questions over open-ended questions due to their ease of answering and consistent grading.

Additionally, the implementation of generative artificial intelligence for generating questions demonstrated that artificial intelligence could effortlessly produce quiz questions without detection by participants. Further highlighting its potential to save resources whilst ensuring high question quality.

Given the impactful role of structured learning outcomes and question formats in digital learning environments, and the emerging role of generative artificial intelligence, further research is essential to fully determine their effectiveness in enhancing learning.

**Keywords** Digital learning, e-learning, generative artificial intelligence, ChatGPT, digital learning environment, ForestBioFacts

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## Tiivistelmä

Digitaalisesta oppimisesta eli e-oppimisesta on tullut mullistava työkalu sekä koulutus- että yrityssektoreilla. Tarkoituksena on edistää oppimista digitaalisilla oppimistyökaluilla, jotka ovat tunnettuja muun muassa itsenäisen opiskelun mahdollistamisesta, motivaation kasvattamisesta ja sen kustannustehokkuudesta. Eduista huolimatta on yhä puutteita liittyen tutkimustietoon osaamistavoitteiden optimoinnista sekä generatiivisen tekoälyn integroinnista digitaalisiin koulutusympäristöihin. Tässä diplomityössä tutkitaan, miten digitaalisissa oppimisympäristöissä voidaan parantaa oppimisen tehokkuutta hyödyntäen esimerkkitapauksena ForestBioFacts-verkkoympäristöä.

Työssä asetettiin kolme tutkimustavoitetta. Ensimmäisenä oppimistavoitteiden tehokas implementointi, toisena eri kysymysmuotojen vaikutusten arviointi oppimiseen ja viimeisenä generatiivisen tekoälyn roolin arviointi digitaalisten oppimisympäristön tehokkuuden lisäämisessä. Tavoitteiden saavuttamiseksi tutkimuksessa hyödynnettiin kvantitatiivista lähestymistapaa, johon sisältyi verkkokokeen lisäksi jälkikysely.

Empiirisessä tutkimuksessa oli kymmenen osallistujaa, jotka jaettiin kahteen ryhmään. Ensimmäiselle ryhmälle jaettiin esimateriaalien lisäksi osaamistavoitteet ja se saavutti jonkin verran korkeamman määrän oikeita vastauksia verrattuna toiseen ryhmään, jolle jaettiin vain esimateriaalit. Tulokset korostavat osaamistavoitteiden merkitystä kognitiivisen kuormituksen vähentämisessä sekä motivaation lisäämisessä. Lisäksi tutkimuksessa tuli esille monivalintakysymysten ja oikein/väärin kysymysten suosio verrattuna avoimiin kysymyksiin johtuen niiden helppoudesta ja johdonmukaisesta arvioinnista. Lisäksi generatiivisen tekoälyn hyödyntäminen kysymysten muodostamisessa osoitti, että tekoäly voi tuottaa kysymyksiä vaivattomasti ilman, että osallistujat epäilevät tekoälyn käyttöä. Tämä korostaa edelleen sen kykyä säästää resursseja ilman, että kysymysten laatu heikkenee.

Koska strukturoiduilla osaamistavoitteilla ja kysymysmuodoilla on merkittävä rooli digitaalisissa oppimisympäristöissä sekä generatiivisen tekoälyn suosio on kasvussa, on aihetta lisätutkimuksiin. Niillä voidaan perusteellisemmin määrittää osaamistavoitteiden, kysymysmuotojen sekä generatiivisen tekoälyn vaikutusta oppimisen tehostamisessa.

**Avainsanat** Digitaalinen oppiminen, e-oppiminen, generatiivinen tekoäly, ChatGPT, digitaalinen oppimisympäristö, ForestBioFacts

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# Preface and acknowledgements

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# Abbreviations

| | |
|---|---|
| E-learning | Electronic learning |
| M-learning | Mobile learning |
| LMS | Learning management system |
| ICT | Information and Communication Technology |
| LMS | Learning management system |
| CMS | Content management system |
| WP | WordPress |
| PDA | Personal digital assistant |
| E-assessment | Electronic assessment |
| FBF | ForestBioFacts |
| AI | Artificial intelligence |
| GenAI | Generative artificial intelligence |
| NLP | Natural language processing |
| ML | Machine learning |
| MCQ | Multiple-choice question |
| DLE | Digital learning environment |
| LO | Learning outcome |

# 1 Introduction

In recent years, significant developments in Information and Communication Technology (ICT) have reshaped many sectors, particularly education. ICT has facilitated the creation of innovative platforms, tools and systems that enhance communication, data processing and access to digital resources (Algahtani, 2011). These developments have introduced new challenges to the educational sector, in particular addressing the shortage of educators and the increasing demand for learning opportunities in higher educations (Algahtani, 2011). Consequently, educational institutions and companies are required to develop effective and efficient systems to meet the global need for knowledge and learning (Amer, 2007).

The significant revolution of the Internet and wireless communication technology has triggered the emergence of diverse interactive multimedia networks. This revolution has paved the way for innovative learning and teaching methodologies that are gaining popularity worldwide. (Holmes & Gardner, 2006). Digital learning or e-learning has become an integral tool in this transformation. It has reshaped both educational and corporate sectors. Digital learning supports self-paced learning, increases motivation, and offers a cost-effective alternative to traditional educational methods (Holmes & Gardner, 2006).

The rise in digital learning initiatives is mainly driven by the need to evaluate their effectiveness, outcomes, and broader impacts (Veletsianos, 2016). Utilising the wide accessibility and convenience of the Internet allows for the integration of digital resources into teaching materials. This integration facilitates the replacement of traditional instruction. Thus, there is a need for extensive research to enhance the performance and expand the utilisation of e-learning platforms globally (Lin et al., 2017).

As learning modes and methods evolve, businesses and governments have significantly invested in the research and development of digital learning platforms. This investment has led to advancements in both the software and hardware used in these platforms. It has also led to the production of diverse digital learning content. Schools and businesses are trying to actively introduce these platforms to enhance learning outcomes. It is essential for educators to implement information technology into their courses, applying different teaching methods and materials to promote efficient learning and activity. (Lin et al., 2017) Digital learning aims to encourage active participation from learners to obtain the set learning outcomes of each learning module (Pai & Tu, 2011).

Although there is an increasing need to integrate digital learning environments (DLEs) into educational systems, significant research gaps remain. DLEs are still in relatively early stages in terms of their widespread adoption, with deficiencies in evaluating their effectiveness in various disciplines. One major gap is the lack of a comprehensive framework to assess how well these platforms support educational activities. (Bates, 2015; Means et al., 2010) Furthermore, while the influence of structured learning outcomes and question formats within DLEs is recognized, there is still limited research on how these elements, with the help of a generative artificial intelligence (GenAI), impact learning effectiveness (Biggs & Tang, 2011; Tanjga, 2023). This situation underscores the need for more focused studies to establish the full potential and benefits of DLEs.

To address this research gap, this thesis aims to explore the effectiveness of digital platforms using ForestBioFacts as an example DLE, to ensure successful learning outcomes. The aim is to thoroughly study the roles of learning outcomes, question formats and generative artificial intelligence to understand their impact on learning effectiveness. Herein the aim is also to outline the conditions necessary for the successful integration of DLEs into educational frameworks. To achieve these objectives, the following research questions are formulated:

RQ1: What constitutes effective learning outcomes, and how can their success be ensured?
RQ2: How do different question formats influence learning outcomes?
RQ3: What role does generative artificial intelligence play in enhancing the efficiency of digital learning environments?

To answer these research questions, an online quiz and a post-questionnaire were used as research methods. The scope of this thesis is focused only on ForestBioFacts as digital learning environment, thus it excludes making general assumptions on other digital learning environments. The results of this study are context specific only to ForestBioFacts.

The thesis consists of a background study, methodology, results, discussions, and conclusions. In the background, the theoretical framework is provided and serves as the literature review, outlining the relevant terms and prior research that guide the study. The methodology describes the experimental part, that aims to give an answer to the research questions. Followed by results and discussion that interpret and analyse the results obtained in the experimental part. Finally, the thesis is concluded and suggestions for further research are provided.

# 2 Background

This background study established the theoretical framework and foundational groundwork for the methodology of this thesis. It begins by outlining the framework used in this thesis to highlight the significance of digital learning and its integral components (learning outcomes, artificial intelligence, and question formats) in enhancing the learning process. Subsequently, this background delves into the concept and principles digital leaning. The section concludes by presenting the effects of learning outcomes and generative artificial on the learning process.

## 2.1 Framework

The framework utilized in this thesis, as illustrated in Figure 1, is derived from the framework introduced by Chan et al. (2003). This master's thesis involves applied scientific research, with its goals mainly focused on practical applications rather than the production of novel scientific knowledge.

The effectiveness of the digital learning environment, in this case ForestBioFacts, is studied by summative evaluation, given that summative evaluation occurs on the completed digital learning environment, which is currently active with a substantial user base. The widespread use of ForestBioFacts makes summative evaluation a suitable evaluation method for assessing the overall impact and success of ForestBioFacts. However, as ForestBioFacts is continuously developing and improving, there is also an opportunity to include formative assessment into the research. This provides insights into the effectiveness of the digital learning environment and identifies opportunities for improvement. The results of the effectiveness of learning in this study has been mainly interpreted quantitatively.

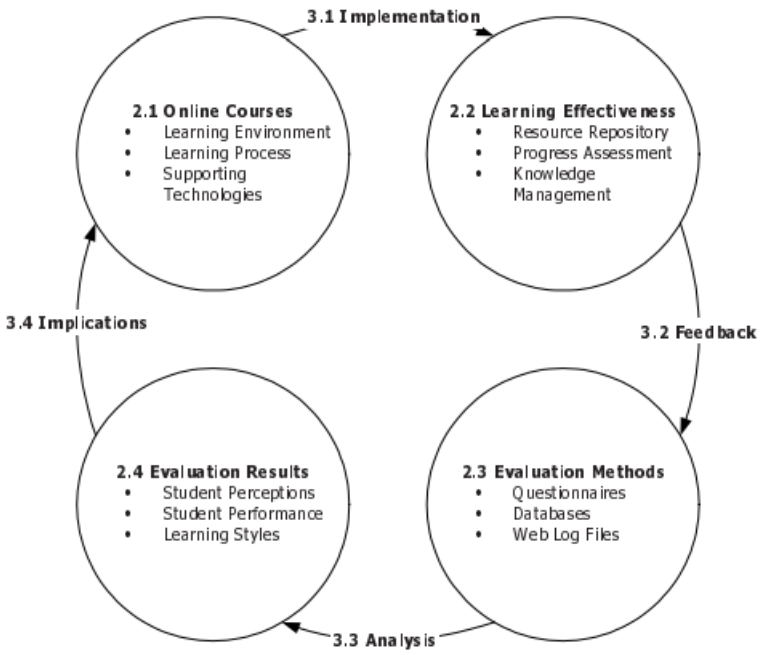


Figure 1. The theoretical framework utilised in this study (Chan et al., 2003).

There are four main components that form the framework: learning effectiveness, evaluation methods, evaluation results, and online courses. Between each component, there are implementation, feedback, analysis, and implication processes.

### 2.1.1 Online courses

Online courses differ from conventional courses in many ways. For instance, conventional classrooms offer only a face-to-face learning environment where educators have an immediate role in the class at a fixed place and time. Whereas in online modules, both learners and educators can learn and teach despite location and time. In online modules, the learning process can be collaborative, independent, continuous, and self-paced. This is facilitated by supporting technologies, like learning management system (LMS) (see section 2.3.2.2).

### 2.1.2 Learning effectiveness

Learning effectiveness is affected by resource repositories, progress assessments, and knowledge management. By enhancing these three factors, learning effectiveness can be increased. For instance, resource repositories (online glossaries, multimedia resources, and refence links) provide a more engaging learning experience beyond conventional text-based resources. Progress assessment involves utilizing student portfolios to assess and monitor their learning performance in the online module. It is also used to

promote learning outcomes. (Chen et al., 2000) Knowledge management, on the other hand, encourages active student engagement and enhances the overall quality of learning experiences by utilizing communication tools like threaded forums and chat rooms online.

### 2.1.3 Evaluation methods

Evaluation methods in the framework include questionnaires, databases, and web log files. Questionnaires are used, for instance, to assess the usefulness of learning resources (Brown et al., 1996) and the implementation of learning tools in LMS (Grabe & Sigler, 2002). Databases are mainly used in online modules to restore information and data. Web log files, in turn, are needed for effectively managing the web server that is hosting the LMS platform.

### 2.1.4 Evaluation results

Evaluation results are the fourth component in the framework. The evaluation results from the evaluation methods have an impact on learning effectiveness. Evaluation results can be analysed from three different perspectives: student perceptions, student performances, and learning styles. In student perceptions, student feedback obtained from questionnaires offers important insight into their perceptions of learning effectiveness. Moreover, assessing student progress allows instructors to refine learning goals. Lastly, analysing web log files gives insights into how users adapt their learning styles in online modules. Understanding the learning styles of students promotes a better assessment approach in online modules (Lee, 2001).

## 2.2 E-learning

E-learning, short for electronic learning, is a method of delivering learning and education that makes use of communications technology. It allows the users to access and create educational materials for learning and teaching, using both electronic devices and the internet. With E-learning, it is also possible to manage courses in an organization. (Fry, 2001; Ng et al., 2021) E-learning is also called web-based learning, distributed learning, online learning, computer assisted instruction, internet-based learning (Ruiz et al., 2006) or digital learning (Kannadhasan et al., 2020). However, for the sake of clarity in this thesis, the terms “e-learning” and “digital learning” will be used interchangeably.

E-learning first emerged in the late 1980s as an alternative to conventional face-to-face learning (Issa et al., 2010). Electronic learning brings together two major areas: learning and technology. Learning is a cognitive process for acquiring knowledge and technology is a facilitator of the learning process, which means that technology is used in the same way as any other tool in the educational praxis, such as pencil or a notebook. (Aparicio et al., 2016)

There are many different ways to categorize the types of e-learning. Algahtani (2011) classified e-learning into two main types: computer-based and internet-based e-learning. Computer-based e-learning utilizes both the hardware (physical components) as well as the software (programs, data, instruction components) in ICT to facilitate the learning process. Both these components can be used in two main ways: computer-managed instruction and computer-assisted learning.

In the computer-managed instruction, computers are mainly used to store and retrieve information as a help in the management of education. However, in computer-assisted learning, computers are used to replace traditional teaching methods. They provide interactive software to support learning in a classroom setting or for independent self-study outside of class. (Algahtani, 2011)

According to Almosa (2001), internet-based learning is a further advancement of computer-based learning. It makes the resources available on the internet with the accessibility of links to related knowledge resources, such as e-mail services and references. The resources would be accessible for use at any time by learners whether or not teachers or instructors are present.

Soon after e-learning, a new form of learning emerged, namely mobile learning (m-learning). It is often discussed alongside e-learning. M-learning is generally defined as learning using devices that are relatively small-size, low weight, low-power consumption, and location independent. Essentially, using devices, such as laptops, smartphones, mobile phones and personal

digital assistants (PDAs) in the learning process. The major advantage of m-learning is that it frees the learners from location-based learning and provides just-in-time learning (Issa et al., 2011). The e-learning literature is wide, and it will continuously grow in the future (Aparicio et al., 2014).

### 2.2.1 Advantages and disadvantages of e-learning

Research conducted by Rosenberg (2001) and Dublin (2003) highlights e-learning as the fastest growing segment of the internet, predicting significant developments in its future. Its role in higher education institutions has notably increased, driving the expansion and implementation of various e-learning tools. These developments have brought about substantial changes in educational performance and support processes within these institutions. The adoption of e-learning in education, particularly in higher educational institutions, offers several benefits and advantages. These advantages include ease of access to a wide range of information (Holmes & Gardner 2006), flexibility of time and place (Smedley, 2010) and its cost effectiveness, enabling learning opportunities for a large number of students without constraints on physical space (Holmes & Gardner 2006). Additionally, e-learning supports self-paced study, allowing students to learn at their own speed, thereby enhancing motivation and reducing stress (Holmes & Gardner 2006). However, the main advantage of e-learning is its learner-centred approach, taking a shift from the traditional teacher-centred model, making education more personalized and effective (Holmes & Gardner 2006; Ozuorcun & Tabak 2012). Beyond educational institutions, e-learning is also extensively utilized for training purposes across various organizations (Rosenberg, 2001).

Despite the advantages of e-learning, it also presents several disadvantages when adopted in education. For instance, digital learning's lack of face-to-face interaction can negatively affect communication skills, potentially leaving learners ill-equipped to effectively share their knowledge with others, despite having excellent academic understanding. (Hameed et al., 2008) This mode of learning can also diminish socialization skills and undermine the effectiveness of instructors' efforts in the educational process. One of the main disadvantages of e-learning that weakens the learning outcomes are academic dishonesty relating to the use of e-learning. (Arkorful & Abaidoo, 2015) For instance, tests and assessment tasks are often indirectly supervised through proxies. This makes it not only difficult but also nearly impossible to manage or control cheating, plagiarism and copy pasting. Furthermore, e-learning cannot be effectively utilized by all disciplines in education. For example, scientific fields that require physical practical experiences may find it challenging to adapt to digital learning. (Arkorful & Abaidoo, 2015) It is argued that e-learning is more suited to the humanities and social sciences

than to fields such as engineering and medical sciences, where developing practical skills is essential. (Arkorful & Abaidoo, 2015)

### 2.2.2 E-learning evaluation

E-learning is deemed effective and successful when the user has the flexibility of learning autonomously, engaging with e-learning content anywhere at any time and pace whilst having positive interaction with instructors and with other users. With the aim of identifying the strengths and weaknesses of e-learning system, it is important and necessary to evaluate the effectiveness of e-learning. Evaluating e-learning is crucial for implementing successful e-learning strategies. (Algahtani, 2011) In an article written by Leung (2003), the significance of ensuring certainty through the evaluation of the effectiveness of e-learning before it is being implemented on a large-scale level was highlighted. The purpose of evaluating e-learning is to lead to development and the development in turn should be based on the results obtained from the evaluation (Reeves & Hedberg, 2003).

According to Reeves and Hedberg (2003), the primary aim of evaluating e-learning is to collect information that supports day-to-day decision-making. Thus, evaluation serves as a way for the continuous improvement of educational software. In addition to evaluation being a method for improving and refining educational software, there are also other reasons behind the need to evaluate e-learning, like evaluating any other activity (Algahtani, 2011). For instance, Sawaan (2005) highlighted that evaluation is to satisfy the curiosity of the users and to provide a clear perspective to stakeholders (designers, developers, experts, and leaders) involved in the enhancement of educational software. Moreover, in a practical context, Dempster (2003), emphasized the versatile purposes of evaluating e-learning. These purposes include assessing the quality of practice and academic teaching, validating investments in e-learning, and enhancing the performance of both individual participants and lesson modules. In summary, as stated by Reeves and Hedberg (2003) “the overall purpose of effectiveness evaluation is to determine whether e-learning accomplishes its objectives within the immediate or short-term context of its implementation”.

Evaluations play a crucial role in the development and implementation of e-learning systems. According to an article by Shobeli (1984), these evaluations are systematically categorized into four distinct stages: initial, formative, summative and follow-up. Each step corresponds to specific phases of e-learning implementation, providing targeted insights into the e-learning system’s effectiveness and areas for improvement. Table 1 offers a comprehensive overview of these stages, detailing their purposes, methods and expected outcomes.

Table 1. A summary of categorization of evaluation types

| **Evaluation stage** | **Methods** | **Purpose** |
|---|---|---|
| Initial evaluation | Pre-implementation data collection | Provide elementary data before starting the application |
| Formative Evaluation | Multiple assessments over time for improvement | Continuous improvement and development during implementation |
| Summative Evaluation | Final assessment at the end of program | Assess effectiveness and decide on the program's future use at the end of implementation |
| Follow-Up Evaluation | Interviews with users and long-term success metrics | Assess the long-term impact and adapt to new developments |

Shobeli's (1984) categorization of e-learning evaluation begins with an initial evaluation. This preliminary evaluation occurs before the system's implementation, aiming to gather essential data before starting the application. The objective is to study the current needs and understanding before starting the e-learning program.

The next step in this evaluation process is formative evaluation. Unlike the one-time assessment of the initial stage, formative evaluation is an iterative process that can occur multiple times throughout the program's implementation. The focus is on the continuous improvement based on ongoing feedback and performance data during the implementation.

Summative evaluation, the third phase in the e-learning evaluation process, is conducted at the end of the program. Its primary purpose is to assess the overall effectiveness of the e-learning initiative and to inform decisions regarding its future application. This phase serves as a final assessment of the program's effectiveness.

After the summative evaluation, the fourth stage, the follow-up evaluation, is conducted to understand the e-learning program's long-term effects and ongoing relevance considering new developments.

As suggested by Shobeli (1984), and further supported by Algahtani (2011), evaluating an e-learning system at various stages throughout its

implementation is critical for enhancing its efficiency. By consistently evaluating e-learning, improvements can be implemented throughout its development process. (Algahtani, 2011)

The effectiveness of e-learning can be evaluated by examining various aspects, including the achievement of learning outcomes, the level of engagement between learners and instructors, learner's prior knowledge, and the retention of information (Noesgaard & Ørngreen, 2015; Yusuf & Al-Banawi, 2013). The most common way of determining the effectiveness of e-learning is through learning outcomes. E-learning is seen as successful when the e-learning modules meet its learning outcomes, and the users gain new knowledge from the module (Noesgaard & Ørngreen, 2015). The amount of e-learning material engages between users and instructors also can be used as an indication to an effective e-learning. When the users are involved in discussions and activities it increases their motivation and desire to both learn the subject and to spend time in the e-learning environment. This engagement can be quantitatively measured and analysed through interaction rates, user feedback, and course completion rates. (Noesgaard & Ørngreen, 2015; Yusuf & Al-Banawi, 2013)

The effectiveness of e-learning is affected by the backgrounds of users, especially their prior experiences and familiarity in digital environments. Such factors influence the initial attitude which learners approach the e-learning modules. Positive and beneficial effects are often observed when there is a correspondence between learner's previous work, online experiences, and the e-learning material. (Mortagy & Boghikian-Whitby, 2008; Haverila, 2010; Bennison & Goos, 2010) Moreover, learning retention is also a key factor in evaluating the effectiveness of e-learning. Effective e-learning occurs when a student retains information well after it was first taught. (Yusuf & Al-Banawi, 2013)

## 2.3 Digital learning environment

Learning environment can be defined as an entity consisting of a place, community, practices, tools, services, and materials, where learning takes place (Finnish national agency for education, 2014). It is important to state that the learning environment in itself does not guarantee learning, but when it is implemented well, it facilitates the work that can lead to learning (Ropo, 2008).

A digital learning environment (DLE) is a technical solution in an online environment that supports teaching, learning and studying activities (Suhonen, 2005). It can be seen as a digital learning tool, educational software, learning resource or as an online study module. Thus, DLE might comprise of various different technical solutions. Hence, Anohina (2005) stated that DLE can be used as the basis for an e-learning module.

The educational and learning opportunities provided by DLEs involve interactions among students, between students and content and between students and teachers (Moore, 1989). Additionally, interactions occur among teachers, teachers with content and within content itself, as stated by Anderson and Garrison (1998). These interactions take place within various organizational structures, for instance in groups, communities and in networks. Understanding how these structures operate enables researchers and designers to understand how participants communicate with each other as individuals (Veletsianos, 2016).

The use of DLEs is encouraged by researchers and educators for two main reasons. First and foremost, in an increasingly digitalized society, learning and education need to embrace digital platforms. Users are encouraged to utilize digital media for both learning and communication. Secondly, DLEs have the potential to enhance the effectiveness and accessibility of teaching and learning. For instance, they can improve user's motivation and adapt to their prior knowledge (Sun, et al 2008; Muenks & Miele, 2017). However, studies indicate that despite the great potential DLEs offer to users, factors like prior knowledge (Connor et al., 2019; Davis et al., 2018), educators (Røkenes & Krumsvik, 2016; Scherer et al., 2019) or the adaptability of the digital setting (Thai et al., 2017) have more significant effects on the learning outcomes than the utilization of DLEs alone. DLEs and e-learning, generally, are both an integral and essential part of a modern learning system. ICT can support learner participation, individual learning paths, and the development do the ability to work collaboratively (Finnish national agency for education, 2014).

## 2.4 Tools used in this thesis

This section aims to discuss and elaborate on the tools that were necessary in order to conduct this research. ForestBioFacts (FBF) is used as an example of digital learning environment. The contents of FBF were utilized to create the quiz questions. See section 5.1 for more detailed information on how the contents of FBF were leveraged. Additionally, this chapter introduces WordPress and LearnDash as the primary tools used to construct the quiz that facilitated this research.

### 2.4.1 ForestBioFacts as case digital learning environment

ForestBioFacts (FBF) is a digital learning environment educating about forest-based bioeconomy. FBF encompasses the whole value chain starting from forest-based products to technologies and sustainable forest-managements.

FBF is designed to provide educational content from diverse viewpoints, including higher education students, teachers, researchers, and industry professionals. By the end of 2023, FBF gained users from nearly 50 global organizations and had over 5000 registered users. Its content is continuously developed and updated by the experts in the field. FBF learning environment consists of 16 themes (Figure 2.), of which the Introduction theme is free.

Figure 2. 16 themes provided by FBF learning environment (ForestBioFacts, 2024)

The content of FBF includes learning paths, a large collection of articles and videos, a virtual paper mill tour, a multi-language dictionary with numerous

terms, a glossary, several webinars, a podcast series, Papermaking Science and Technology book series and an audiobook operated by artificial intelligence available in different languages. More detailed description of the content can be found in Table 2.

Table 2. A detailed description of different features of ForestBioFacts.

| **Features** | **Description** | **Purpose** |
|---|---|---|
| Learning Paths | Two learning paths: Learning Path A (beginner friendly) and Learning Path B (advanced) | Guide learners through structures educational journeys. |
| Articles | 1600+ articles | Provide in-depth knowledge and research insights. |
| Videos | 300+ videos | For visual learning |
| Virtual paper mill tour | An interactive virtual tour | To offer a three-dimensional mill experience |
| Dictionary | 6-language dictionary with 6000 terms | Expand technical vocabulary in different languages |
| Glossary | Comprehensive glossary | Clarify key terms and concepts in the field |
| Webinars | 15+ webinars | Live interactive learning and expert insights |
| Podcast series | called “Wonders of Wood and Beyond” | Engage listeners with informative discussions and stories |
| Book series | called “Papermaking Science and Technology” in PDF format | Provide comprehensive academic information in a convenient format |
| Audiobook | Available in 6 languages (English, Germany, Finnish, Spanish, Portuguese and Chinese) | Make content accessible in multiple languages utilising artificial intelligence |

There were more than 150 top professionals in the academia and industry in close collaboration in the development and planning of ForestBioFacts. The learning environment has been developed based on the Papermaking Science and Technology book series. However, FBF discusses forest-based bioeconomy more thoroughly. Shifting from a conventional book series to digital learning environment allows for timely content updates, diverse functionalities, system customization and improves accessibility to content and information. With FBF it is possible to enhance learning, motivate

students and maintain the general competence level in the forest-based industry.

ForestBioFacts is a protected website, and it was developed utilizing WordPress in 2020. It is available for companies, universities and for private users. Company licenses, based on their annual turnover are offered for 1, 3 or 5 years, and it is possible to purchase the license through ForestBioFacts website. For private users, they can purchase the access for private use also in online store. They can buy an access for 3, 6 or 12 months for either individual themes or for the whole content.

### 2.4.2 WordPress

WordPress (WP) is an open-source content management system (CMS) and it is being actively contributed to by many developers. A CMS in general, facilitates the publication and creation of digital content. CMS is suitable for developing static websites, forums, online stores, and a variety of other digital formats. (Cabot, 2018) The three most used and successful CMSs are Joomla, Drupal, and WordPress (Fernandes & Vidyasagar, 2015).

WP was first developed in 2003 and has now grown into being one of the largest self-hosted blogging tools. Millions of sites alongside with tens of millions of users have been developed by using WordPress. It is available for use without requirement of payment of licensing fees. Customers can utilize WP for instance for their homepage or website without any charges for the software itself. (Fernandes & Vidyasagar, 2015)

### 2.4.3 LearnDash LMS

A learning management system (LMS) is a widely used term and generally it refers to versatile systems that offer online educational services for students, teachers, and administrators (Aldiab et al., 2019). Kaplan-Leiserson (2000) defines LMS as “LMS (learning management system): Software that automates the administration of training events. The LMS registers users, tracks courses in a catalogue, and records data from learners; it also provides reports to management. An LMS is typically designed to handle courses by multiple publishers and providers. It usually doesn't include its own authoring capabilities; instead, it focuses on managing courses created by a variety of other sources.” While the term “online learning platform” is sometimes used interchangeably (Paulsen, 2002), this thesis uses term LMS.

LMSs are developed to present, follow up, manage, and assess all learning task via the internet. Thus, it is used for providing access and organizing

online learning services. With these learning services, it is possible to limit the access control authorised people, provide both various types of interaction tools and different types of learning material. (Aldiab et al., 2019) LMS are not only implemented in educational institutions, but also in businesses and government agencies (Kirvan & Brush 2023; Tanwar, 2022). Some popular and successful LMSs used in educational institutions include Blackboard and Moodle, (Aldiab et al., 2019) while enterprise-lever LMSs include Adobe Learning manager, eFront and LearnDash (Kirvan & Brush 2023; Tanwar, 2022).

LearnDash is a WordPress LMS Plugin, utilised by companies, entrepreneurs, and universities worldwide. LearnDash allows the users to create, sell and track user progress of the modules and deliver certificates among other many features. LearnDash is a popular choice of LMS for developing online modules as it is versatile and easy to use. However, LearnDash Plugin is sold only as an annual license for a certain amount of money. (LearnDash, 2023)

LearnDash Plugin has been installed in ForestBioFacts digital learning environment and it will be used as a LMS tool to conduct the research and obtain the results needed for this thesis.

## 2.5 Learning outcomes

The conventional method for designing courses and learning modules typically began with teachers outlining the content they planned to teach. Followed by creating instructional plans and assessing the material (Kennedy et al., 2007). This typical approach concentrated on both the educator's input and on evaluating how well the students learned and comprehended the material taught (Kennedy et al., 2007). Additionally, course descriptions provided an overview of the content that would be covered in the lectures. This type of approach to teaching is also known as teacher-centred approach (Kennedy et al., 2007). The teacher-centred approach has received criticism in literature. For instance, Gosling & Moon (2001) argued that it is challenging to identify precisely what the student must do to successfully pass the learning module or the course.

Academia has faced changes, and it has evolved from the traditional teacher-centred approach to a student-centred approach. Student-centred approach focuses on what the learners are meant to be able to do at the end of the learning module. Thus, it is also commonly known as intended learning outcomes or just learning outcomes (LOs). (Kennedy et al., 2007)

The whole concept of learning outcomes can be linked back to the work of the behavioural objectives movement from the 60s and 70s in the United States.

Robert Mager was the main supporter of this movement. He proposed an idea of writing very distinct statements regarding observable outcomes. He called these statements instructional objectives (Mager, 1984). By using these instructional objectives, he attempted to specify the type of learning that would take place at the end of the instructional process. It involves specifying the classification of knowledge, understanding or skills that learners are expected to obtain. The determination of the learning type is not only about identifying what will be learned but also understanding how that learning will be assessed or evaluated. Instructional objectives involve defining the content and the criteria for measuring the success of the learning process, which later evolved into more precisely defined learning outcomes.

### 2.5.1 Definitions of learning outcomes

There are many different but similar definitions of learning outcomes in literature. Common definitions for learning outcomes can be seen in Table 3.

Table 3. Common definitions for learning outcomes.

| Definition | Main focus | Author(s) and year |
|---|---|---|
| Learning outcomes are statements that describe what the student is expected to be able to do as a result of learning the activity. | Outcome expectation | Jenkins & Unwin (2001) |
| Learning outcomes are specific description of what student should know, understand and be able to do as a result of their studies. | Knowledge and skills acquisition | Bingham (1999) |
| A learning outcome is a statement that describes what a student is anticipated to know, understand, and/or be able to demonstrate at the end of a learning module. | Knowledge, understanding and demonstration | Gosling & moon (2001) |
| A learning outcome is defined as a statement that described what the student should know, understand, and/or be able to demonstrate at the end of a learning module. | Knowledge, understanding, and demonstration | Donnely & Fitzmaurice (2005) |
| A learning outcome is defined as a statement of what a student should know, understand and be able to do at the end of a learning module and of how that learning is meant to be demonstrated. | Knowledge, understanding, skills and demonstration | Moon (2002) |
| A learning outcome is defined as a written statement that describes what the successful student should be able to do at the end of a learning module or qualification. | Written statement of learning outcomes and student success | Adam (2004) |

As can be seen the given definitions of LOs show no significant differences. Therefore, it is evident that LOs focus on what the learner has achieved rather than the intensions of the teachers. Additionally, learning outcomes emphasize what the student can demonstrate at the end of the learning activity. (Kennedy et al., 2007)

### 2.5.2 Difference between learning objectives and learning outcomes

As LOs focus on the achievements of a student, learning objectives of a learning module is often a specific statement that describes what learners should do to achieve to reach the outcomes. Learning objectives depict the specific areas that the teachers intend to cover in the learning module. In other words, outlining one of the specific areas that the teacher plans to cover in the module. (Kennedy et al., 2007) In some cases, objectives are also referred to as learning goals.

However, there are some challenges associated with the use of learning objectives. In some cases, learning objectives are written in terms of teaching intentions while in others they are expressed in terms of expected learning. (Kennedy et al., 2007). Consequently, this has led to confusion in the literature about whether learning objectives are part of teacher-centred or an outcome-centred approach. On the other hand, LOs are more specific and easier to compose than learning objectives (Kennedy et al., 2007).

### 2.5.3 Bloom's taxonomy

Writing learning outcomes is an integral part of the implementation phase of designing a learning module. The work of Benjamin Bloom provides a useful starting point when working on writing learning outcomes. Bloom worked on research (Bloom et al., 1956) on the development of a categorization of levels of thinking in the learning process. Bloom suggested that the educators should design tasks and lessons to help the learners to meet their learning objectives. He identified three domains of learning: cognitive, psycho-motor, and affective, of which the cognitive domain is his most advanced work. In the cognitive domain, he created a classification or taxonomy system (called Bloom's taxonomy) that categorizes many thinking behaviours within the cognitive domain (Bloom et al., 1956).

In Bloom's taxonomy, the cognitive domain is composed of six successive levels (knowledge, comprehension, application, analysis, synthesis and evaluation) arranged in a hierarchy. In the hierarchy (Figure 3) Bloom and his colleagues (1956), claimed that the student can move onto a higher level of learning only after mastering/comprehending the one below, since the lower level is a prerequisite for the higher level. They also stated that the higher level automatically includes the lower level, implying that the levels of

learning ought to be organized in a specific order: simplest at the bottom and the most complex at the top of the triangle.

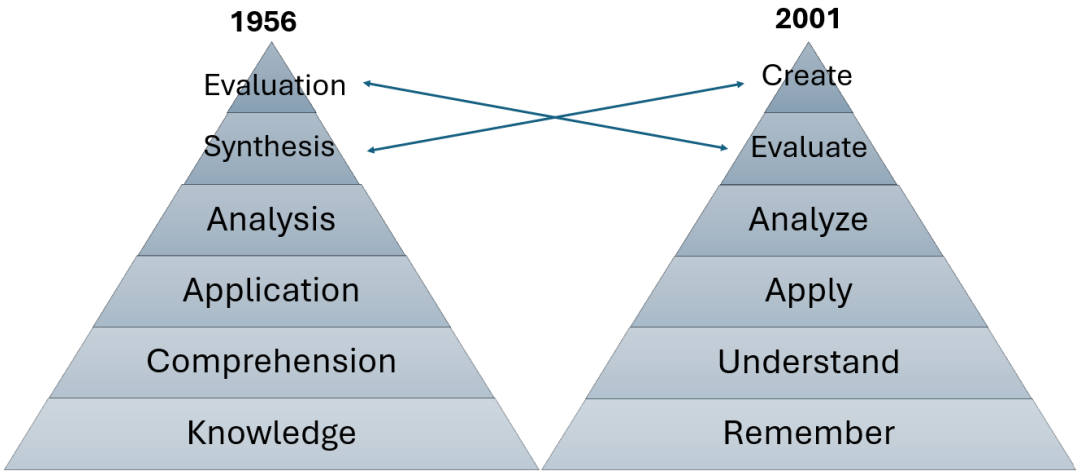


Figure 3. The updated Bloom's taxonomy, where one of the changes made was from noun form to verb form (adapted from Darwazeh, 2017)

Anderson & Krathwohl updated the bloom's taxonomy in 2001 and renamed the knowledge into "remember", synthesis into "create" and comprehension into "understanding. Additionally, Anderson changed the place of synthesis (create) at the top of the triangle (Figure 3). Bloom's taxonomy is widely used all over the world to help in preparing both curriculum and assessment materials (Darwazeh, 2017).

### 2.5.4 Learning outcomes, teaching and assessment

It is important to write learning outcomes in a way that they can be assessed. Additionally, it is also important to utilize some type of assessment tool or technique to determine the extent to whether learning outcomes have been achieved successfully. Assessment techniques or tools can be direct or indirect. For instance, direct assessment techniques include the use of written examinations, portfolios, project work, theses, grading system with rubrics and reflective journals. On the other hand, examples of indirect assessment tools are analysis of curriculum and surveys of both employers and graduates. (Kennedy et al., 2007)

For educators, it can be challenging to ensure alignment between assessment techniques, assessment criteria, teaching methods and learning outcomes. However, finding these alignments and connections helps to make the learning experience more transparent (Kennedy et al., 2007). It has been shown that clear expectations in student course evaluation are a critically important part of effective learning. The lack of clear expectations can result in learning difficulties, poor student performance and in negative evaluation

(Kennedy et al., 2007). According to Toohey (1999) the effective way to help learners understand how they should achieve learning outcomes is by clarifying the assessment criteria and the assessment techniques. Assessment techniques should always mirror the learning outcomes (Kennedy et al., 2017).

#### 2.5.4.1 E-assessment

The advancement of technology and e-learning systems has led to an increased demand for effective assessment methods (Brink & Lautenbach, 2011). As the number of students is increasing in higher education institutions, the educators have an increased workload in terms of organizing the course. In response to this challenge, e-assessment can offer a viable solution for institutions. (Walker at al., 2008)

Electronic assessment (e-assessment) is the use of any electronic devices to deliver, create, store, give feedback and to report the assessment marks of students (Crisp et al., 2011; Howarth, 201). Laptops, mobile phones, tablets and desktop computers and other electronic gadgets are examples of tools for generating and implementing e-assessment activities (Crisp et al., 2011; Howarth, 2015). Different content formats, such as Word documents, videos, portable document formats (pdf) or games can be utilized to support e-assessment. Additionally, through e-assessment it is also possible to test the abilities and skills of students (Crisp et al., 2011). E-assessment is a component of e-learning with the potential to emerge as the preferred form of assessment compared to the traditional methods (Appiah & van Tonder, 2018). Thus, if and when technology is effectively implemented in the process of assessments, it has the capability to enhance the learning experience of the students (Appiah & van Tonder, 2018).

According to Howarth (2015), e-assessment system is usually composed of two main components: an assessment engine and an item bank. An assessment engine consists of both soft and hardware which are needed to deliver and design for instance a test or an assessment task. An item bank on the other hand contains instructions, questions, or both. In the item bank the contents are randomly generated by the assessment engine to deliver the test or the task.

The assessment tasks of e-assessment are provided to the students by two modes of delivery: by web-based delivery or by download delivery. In web-based delivery, the students access the assessment task via Internet (online e-assessment). This means that the students can access the e-learning activities anywhere at any time provided that there is a working Internet connection. (Naidu, 2006; Algahtani, 2011; Romiszowski, 2004) On the other hand, in download delivery the assessment tests and tasks are uploaded onto students' computers in advance, and they become available to the

students after arriving at the assessment location at the scheduled time and date. Download delivery is known as offline e-assessment. (Naidu, 2006; Algahtani, 2011; Romiszowski, 2004). Download delivery is the preferred method of delivering e-assessment for high-stakes examination and more security measures are taken to avoid unwanted exposure of the assessment (Howarth, 2015).

Various types of e-assessment can be implemented in e-learning/digital learning, including summative e-assessment, formative e-assessment, e-self assessment, and e-peer assessment (Prendes-Espinosa et al., 2022). Table 4, provides and overview of these e-assessment types, highlighting their characteristics, purposes and typically used digital tools in their execution.

Table 4. Types of e-assessment in digital learning

| **Type of e-assessment** | **Description** | **Purpose** | **Tools used** | **Author(s) and year** |
|---|---|---|---|---|
| Summative e-assessment | Evaluated at the end of a learning period, assessing overall comprehension and performance | Evaluate the effectiveness of the learning experience. | Quizzes, forums | Prendes-Espinosa et al., (2022); Sewell et al., (2010) |
| Formative e-assessment | Continuous observation and feedback to improve learning outcomes, giving learners more responsibility. | Identify strengths and weaknesses, promote self-awareness and address academic needs. | Forums, chats, blogs | Irons (2008); Colmenares (2012) |
| E-self assessment | Learners reflectively examine their strengths and weaknesses in relation to learning objectives. | Foster self-assessment and improvement. | Online questionnaires, e-portfolios | Mosqueda (2018) |
| E-peer assessment | Exchange of feedback among peers, with roles as assessors or asses. | Facilitate peer feedback and collaborative learning. | Social networks, videoconference tools | Lu & Law (2012) |

In summative e-assessment the results are obtained at the end of lessons, courses or projects using digital tools, like quizzes and forums. The aim is to

evaluate the overall comprehension and performance of the learner. It is used to assess the effectiveness of the learning experience. (Sewell et al., 2010)

Formative e-assessment is used to observe student learning and provide feedback to improve intended learning outcomes and to give the learners more responsibility for their learning (Irons, 2008). According to Colmenares (2012), in formative e-assessment, educators identify the strengths and weaknesses of each learner utilizing platforms such as forums, chats, blogs or other digital devices. This process enables self-awareness among learners, thus allowing them to proactively address their academic needs.

E-self assessment involves a reflective examination with the purpose of identifying weaknesses and strengths related to achieving the objectives of the learners. This process is utilized using online questionnaires or alternative methods like e-portfolios. (Mosqueda, 2018)

Lastly, e-peer assessment involves the digital exchange of feedback among the learners who give and receive digital feedback from their peers. The process in e-peer assessment is characterized by learners defining their roles as either assessors or assesses. The assessment is typically facilitated through social networks, videoconference tools and similar platforms. (Lu & Law, 2012)

#### 2.5.4.2 Question formats used in e-assessment

Assessing learning is a critical tool in the educational process that extends beyond measuring knowledge and competence. It also guides and facilitates learning and provides feedback to both teachers and learners. (Hift, 2014) The importance of assessment is further highlighted by research. Studies suggest that assessment not only consolidates learning, but also enhances and facilitates memorisation and recall. The act of testing itself stimulates recall, and thus enhances both the learning and retention of the content (Hift, 2014). There are many different assessment methods used in online learning (see section 2.5.4.1). For this thesis a quiz was chosen as the assessment method. Thus summative e-assessment was considered the most suitable approach in terms of resources and timing. Consequently, this section highlights the importance of question formats used in summative assessment.

There are typically two types of written questions: open-ended or closed-ended questions. In open-ended questions, the respondent must generate an answer in phrases, sentences or in words. Conversely, closed-ended questions provide a list of option from which the respondent must select the correct answer. (Gharehbagh et al., 2022) Closed questions comprises of a stem, which can be a statement, a question, or a case example. It also contains

an item, in which potential answers are displayed below in form of a multiple sentences (Haladyna et al., 2002). Respondents are required to evaluate each option and choose the correct one among the incorrect options, also known as distractors. (Enders, et al., 2021; Hubbard et al., 2017) Formats of closed questions vary, for instance, single-choice questions have only one correct answer among at least three options, multiple-choice questions MCQs may have more than one correct options and true/false questions require a binary choice regarding the statement's accuracy ("true vs. false"/" correct vs. incorrect") (Enders et al., 2021).

The closed-question format offers many benefits, including objectivity, efficiency, ease of grading and transparency. This question format increases grading objectivity, which not only reduces inconsistencies but also increases reliability of the results (Gharehbagh et al., 2022). However, it has limitations such as low face validity, time-consuming question construction. Additionally, they may encourage superficial reading and memorisation of content (Gharehbagh et al., 2022).

Open-ended questions have been used as the main tool for assessing for many years. Nonetheless, many problems have been emerged from the implementation of open-ended questions. For instance, participants feel deep dissatisfaction with the limited time available for responses, low scoring reliability among educators, grading inconsistencies and inadequate coverage of course content with these questions (Gharehbagh et al., 2022; Hubbard et al., 2017). Despite these limitations, open-ended questions reduce the probability of cheating and guessing since they do not provide a list of options, thus forcing participants to generate their answers (Gharehbagh et al., 2022).

It is important to note that neither the format nor the form of a question determine its ability to assess the intended level of learning. The content of the questions is what determines the evaluated level of learning and knowledge. When deciding on the assessment method and question formats, the educational goals and learning outcomes should be considered (Gharehbagh et al., 2022).

#### 2.5.4.3 Benefits and challenges in e-assessment

E-assessment has many benefits, regardless of the chosen e-assessment type. Many students can be examined within a specified timeframe using e-assessment, particularly if their answers are marked automatically. Additional educational benefits include immediate lecturer and student feedback, the possibility to repeat and randomize tests, the reliability and fairness provided by computer-based gradings, the flexibility for students to

complete the tasks at their own pace and convenience regardless the location (resulting in time savings), and the creation of opportunities for students to take responsibility for their own learning (Morris, 2008; Chalmers & McAusland, 2002; Howarth, 2015; Appiah & van Tonder, 2018).

Despite the advantages of e-assessment, there are also some disadvantages in utilizing e-assessment. Based on the study conducted by Brink and Lautenbach (2010), the major challenge in using e-assessment is security, since users can access the e-assessment tasks from anywhere. Educators not being comfortable with the use of e-assessment often tend to design poor assessment tasks and tests, which hinders learning (Mackenzie, 2003). Another disadvantage is inequality in e-assessments. As reported by Clariana and Wallace (2002), better performing students did well in computer-assisted assessment tasks compared to traditional assessment tests. They noted that these students could easily adjust to new assessment methods. They stated that computer-assisted assessment might not be reasonable to lower-performing students, as they find completing e-assessments to be time-consuming and demanding.

While e-assessment offers various benefits, its successful implementation requires addressing the challenges of educator readiness and the potential for inequal outcomes amongst the students. Therefore, it is important to highlight the ongoing research and take proactive measures to increase the effectiveness and inclusivity of e-assessment in educational environments.

## 2.6 Generative artificial intelligence in e-learning

Artificial intelligence (AI) encompasses the development of intelligent machines capable of performing tasks that typically require human cognitive abilities, such as perception, learning, reasoning, and decision-making (Gligorea et al., 2023). As a transformative technology, AI has become crucial in many sectors, including education (ibid).

The global adoption of e-learning systems has significantly accelerated since the COVID-19 pandemic, highlighting the essential need for innovative and new solutions to support remote learning (Tanjga, 2023). This shift has highlighted the critical role of AI as a promising tool for the challenges of traditional e-learning methods by enabling adaptive assessment methods, personalized learning paths, and intelligent tutoring system. Resulting in improved learning outcomes for student (Tanjga, 2023).

One promising tool in revolutionizing e-learning systems is generative artificial intelligence (GenAI), a subset of AI that specializes in generating new information when prompted. Unlike conventional AI, which performs task based on pre-training, generative AI uses natural language processing

(NLP), machine learning (ML) and other technologies to learn from already existing data and produce outputs. This capability makes it particularly valuable in e-learning contexts, where it can offer rapid customization of learning materials according to individual learner needs and it can also work as a tutor for students. AI-based mentors and tutors are available for the students uninterrupted, and they answer all questions and can provide immediate feedback. The integration of generative AI into e-learning systems can significantly enhance the learning experience. (Tanjga, 2023; Rupareliya,2023)

An innovative example of a GenAI tool is ChatGPT. ChatGPT got published by OpenAI in 2022 and in 5 days it reached 1 million users (Firat, 2023). Many of the users got the chance to experience the abilities of a generative AI (First, 2023). ChatGPT is engineered to engage in conversations with humans using natural language, offering precise and useful answers to a wide range of questions (Tanjga, 2023).

In the empirical section of the thesis, ChatGPT 4.0 is used to generate questions upon prompting (see section 3.1.2). The objective is to explore the feasibility of utilizing generative AI within e-learning systems. Despite the innovative opportunities GenAI provides, it is still important to acknowledge the potential issues and challenges associated with its use (Tanjga, 2023). While generative AI can provide helpful and accurate responses, there is still the possibility of inaccuracies and errors, especially if the system has not been trained properly on a wide range of educational content (Tanjga, 2023). Additionally, there are ethical concerns, such as privacy data protection and the risk of bias surrounding the use of generative AI. Ensuring that the AI system is developed and operated with ethical considerations in mind, alongside safeguarding and properly managing student data, is crucial (Tanjga, 2023).

# 3 Methodology

In order to answer the research questions of the thesis, two methods were used to obtain data. The study conducted in this thesis is a quantitative study with both explanatory and exploratory characteristics. Both the quiz and the survey were conducted as a quantitative study. This section of the thesis describes the methods used to collect and analyse data. The overall research process can be seen in Figure 4.

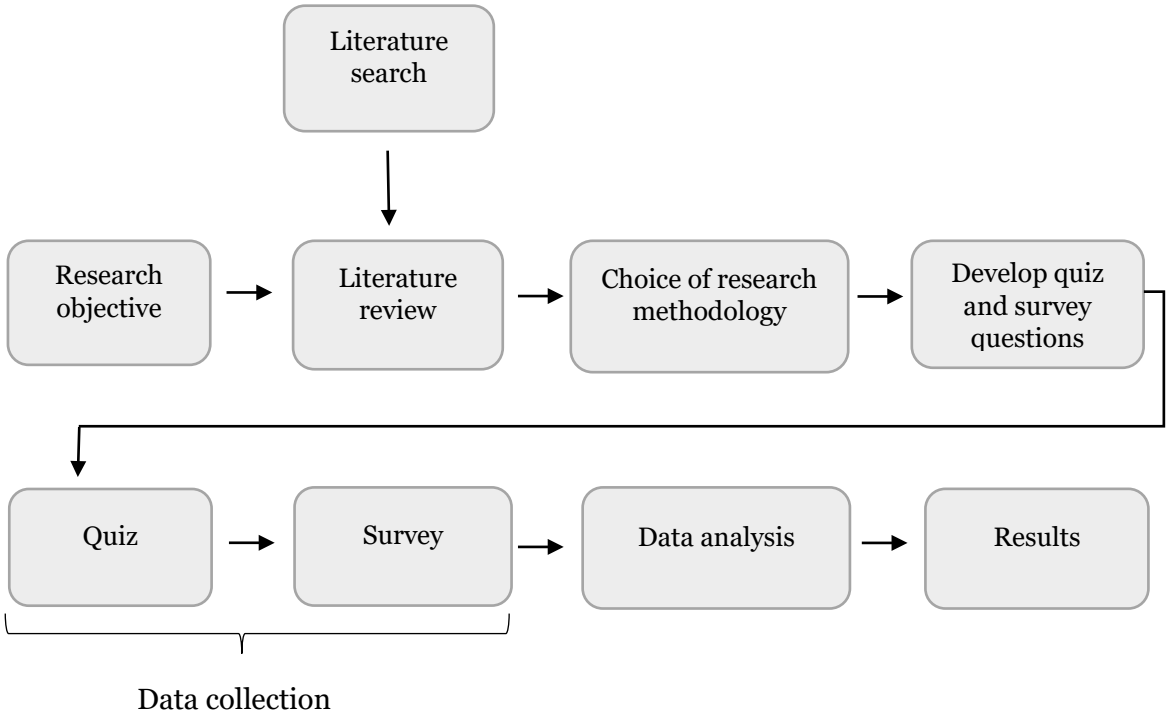


Figure 4. A scheme of the overall research process.

## 3.1 Data collection

In this subsection, the data collection process is presented, and the methods used are described. Both a quiz and a survey were conducted.

### 3.1.1 Quiz

In the quiz the aim was to gather data to assess the success of digital learning using FBF as a case digital learning environment. Quizzes generally have different question types, of which the most commonly used are multiple-choice (MC), true/false, open-ended and matrix sorting questions (Dario, 2022). Thus, this quiz also had similar question formats.

The quiz was created using LearnDash by first selecting the “Quizzes” from the menu option and then clicking the “Add new” button at the top of the page. Next, the required details, such as the quiz title and the instructions or additional information were added. After creating the quiz and adding the title, the questions were created by clicking the “Builder” tab in the top navigation bar. The settings visible to the quiz maker will be referred to as the back end in this thesis, while the format of the questions visible to the user will be referred to as the front-end.

New questions were added to the quiz by selecting the “+New Question” link located at the bottom of the quiz builder. Upon clicking this link, the title of the question was entered, followed by clicking the “Add Question” button. To choose the question format, the question entry was expanded by clicking on the blue down arrow to the right, and the desired question type was selected from the dropdown menu. LearnDash offers eight different question formats to choose from. These include, Single choice, Multiple Choice, Free Choice, Sorting choice, Matrix sorting choice, Fill in the blank, Assessment and lastly Essay/Open Answer. In this quiz, the following types of questions were selected: Single choice, Essay/Open Answer, multiple-choice, and Matrix Sorting choice.

The settings of the questions were customized to fit each question type. For instance, for single choice question, the question type was selected from a dropdown menu, and the question was written along with the different answer options. The correct answer was indicated by a single radio button. For multiple-choice questions (MCQs), checkboxes corresponding to the correct answer were selected. In the quiz builder, the correct answer(s) were displayed in bold.

For Matrix sorting choice questions, the question type was chosen similarly to single and multiple choice from the dropdown menu. There were two parts to the matrix sorting question: “Criterion” and “Sort elements”. For the criterion, the link to the image with quotation marks was added using “<img src=” at the beginning of the link and “alt= />” at the end of the link. Additionally, the “Allow HTML” checkbox was selected. For the Sort elements, the corresponding word was written, which users would drag and drop to the correct criterion.

Lastly, for the essay/open answer, the question type was selected, and the question was written. These questions allowed the users to enter free-form answers. There were two answer format options available, but for this quiz only the text entry option was selected. The different question types used and front-end and back-end examples of the questions in the quiz are summarized in Table 5.

Table 5. A detailed description of the question formats and their number used in the quiz.

| **Used question types** | **The number of each question types** | **Front-end example of a question** | **Back-end example of a question** |
|---|---|---|---|
| Single choice | 8 | Figure 5a. | Figure 5b. |
| Matrix sorting choice | 2 | Appendix I. | Appendix I. |
| Multiple choice | 5 | Appendix I. | Appendix I. |
| Essay / Open answer | 4 | Appendix I. | Appendix I. |

The settings for this quiz were tailored to ensure technical functionality. The quiz progress saving feature was activated, allowing progress to be saved to the server. Additionally, features such as the "question overview table", "quiz summary", "skip question", "restart quiz button" and "quiz statistics" were all enabled.

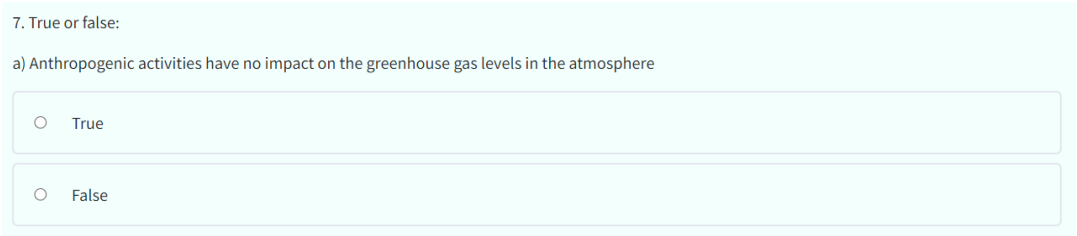


Figure 5a. An example of a front-end single choice question used in the quiz.

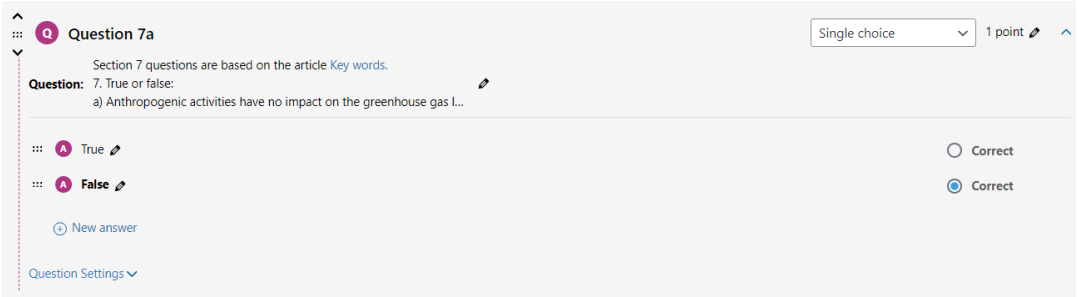


Figure 5b. An example of a back-end single choice question used in the quiz.

### 3.1.2 Material applied as base for questions

For the creation of the questions, different materials were used for human-made questions and AI-based questions. The quiz comprised a total of 19 questions: the first 11 (questions 1-11) were generated using ChatGPT 4.0.

and the remaining eight questions (questions 12-19) were human-made. The quiz questions are listed in Appendix III. The materials used as a basis for questions were given as pre-materials to the participants.

The AI-generated questions were based on the FBF articles "The bioeconomy is humankind"s greatest opportunity", "Carbon cycle and circular bioeconomy" and "Key words" under the introductory theme "Introduction to forest-based bioeconomy", which are available to all. Before generating the questions, ChatGPT 4.0 was provided with texts from these articles upon prompts. The prompts used to generate the questions are listed in Table 6.

Table 6. Prompts used to generate questions using ChatGPT.

| **Prompt number** | **Question type** | **Used prompt** | **Additional details** |
|---|---|---|---|
| 1 | MCQ with single correct answer | Based on the text I have provided for you, can you give me X multiple choice questions for me with one correct answer. | "X" indicates the number of questions ChatGPT generates. In this prompt, ChatGPT was asked to generate three questions |
| 2 | MCQ, with more than one correct answer | Based on the text I have provided for you, can you give me X multiple choice questions with more than one correct answer | "X" indicates the number of questions ChatGPT generates. In this prompt, ChatGPT was asked to generate three questions |
| 3 | True or false | Based on the text I have provided for you, can you make me X true or false questions or sentences | "X" indicates the number of questions ChatGPT generates. In this prompt, ChatGPT was asked to generate five questions |
| 4 | Open ended | Based on the text I have provided for you, can you make me X straightforward open-ended questions alongside with model answer. However, keep in mind that the questions should be possible to answer in maximum two sentences and add the instruction on the questions. | "X" indicates the number of questions ChatGPT generates. In this prompt, ChatGPT was asked to generate two questions |

The human-made questions (questions 12-19) were developed with the help of a University Lecturer from Aalto University. These human-generated questions were based on the articles within the “Converting of paper and board” section under the licensed theme of “Natural fibre products”. This theme was only available to users after having paid for the license to access FBF. Since, ChatGPT uses the input content to train their models although there is an option to click “do not train on my content”, they still retain the prompts in their database (OpenAI, 2023), thus it was chosen not to feed the licensed material into ChatGPT 4.0.

### 3.1.3 Post-questionnaire

In the post-questionnaire, the aim was to gather qualitative and quantitative data on the research topic, and to complement and verify the results of the quiz. Furthermore, this deductive research approach facilitates the collection of data that are typically straightforward to score or tabulate. The obtained data are also easier to analyse, especially when the questionnaire primarily consists of questions with predefined answer options from which respondents can choose from (Patten, 2017; Saunders et al., 2007). Regarding the research objectives, a post-questionnaire was deemed as a suitable data collection method.

The questionnaire outline was based on the research questions, quiz content and literature review. A total of 14 questions were formulated (see Appendix IV Post-questionnaire questions). The majority of questions were close-ended, requiring specific answers, alongside a couple of open-ended questions that allowed the respondents to elaborate more with their responses. In some of the close-ended questions, the respondents were asked to choose using a ranking scale of 1-5. On this scale a value of 1 corresponds to “All AI”, indicating that all questions were generated by AI. Conversely, a value of 5 corresponds to “None of AI”, where none of the questions were generated by AI. The lower values on the scale indicated a higher presumed presence of AI in the question generation, while the higher values suggested a higher presence of human-made in the question generation.

The wording of the questions was carefully chosen to avoid misunderstandings and to ensure clarity and conciseness. The questionnaire was created using Google Forms. After its initial development, it was further refined and validated based on the feedback from colleagues within Finnish Forest Products Engineers’ Association. The post-questionnaire was designed to be completed by the same participants who had taken the quiz beforehand.

## 3.2 Conducting the research

The participants for this test were recruited from the network of the Finnish Forest Products Engineers' Association and Aalto University. Their age, gender or other demographic information weren't asked.

A total of 10 participants took place in the research, starting with a quiz followed by a post-questionnaire. The participants were mostly master's students from Aalto University with the exception of a one participant that was recently graduated.

The 10 participants were divided into two groups. Group 1 had five participants (Participants 1-5) and they were given learning outcomes (see Appendix II) and pre-materials two days prior to the testing day. Group 2 also had five participants (Participants 6-10) and they were given the same pre-materials but without the learning outcomes. The aim was to determine whether providing learning outcomes would affect the quiz results in any way. Table 7 shows the participants who took part in both the quiz and the post-questionnaire.

Table 7. A summary of the research participants.

| **Participants** | **Academic level** | **Testing environment** |
|---|---|---|
| Participant 1 (Group 1) | Master's | Aalto university |
| Participant 2 (Group 1) | Master's | Aalto university |
| Participant 3 (Group 1) | Recently graduated | Aalto university |
| Participant 4 (Group 1) | Master's | Aalto university |
| Participant 5 (Group 1) | Master's | Aalto university |
| Participant 6 (Group 2) | Master's | Aalto university |
| Participant 7 (Group 2) | Bachelor's & Master's | Aalto university |
| Participant 8 (Group 2) | Master's | Aalto university |
| Participant 9 (Group 2) | Master's | Aalto university |
| Participant 10 (Group 2) | Master's | Aalto university |

After the two groups were divided and taken into two different meeting rooms at Aalto university, the research began with the participants first taking the quiz, which was an open-book format. Participants accessed the quiz using ForestBioFacts their own laptops. The quiz was conducted in a supervised environment to eliminate the possibility of academic dishonesty as it is one of the main disadvantages of digital learning (see section 2.2.1.). They were given 60 minutes to finish the quiz. After finishing the quiz, the participants were sent a link to the survey via email, and they were instructed

to fill it in as soon as they submitted their quiz results. Both the quiz and the post-questionnaire were conducted in English.

Based on the nature of the quiz and the post-questionnaire, descriptive statistics were considered as s suitable method for analysing the collected data. Descriptive statistics is easy and useful method when wanting to summarise data and to provide a description of the sample (Marshall & Jonker, 2010).

The research was conducted following the principles of a good scientific practice (Finnish national board on research integrity, 2021). The results of the quiz and the survey have been processed confidentially and anonymously. Within the results, it is not possible to identify individual participants. Despite not collecting or storing personal data of the participants, they read and agreed to the privacy policy.

## 3.3 Methodological limitations

The research methods utilised in this thesis has some limitation. For instance, due to the time and resource constraints, there was a limited number of participants. Due to the small number of participants, the research methods have prevented making broad generalizations from the findings. However, the sample size was deemed adequate to provide sufficient data for answering the research questions. The reliability of the study was reinforced by designing and analysing the results of the research together with the colleagues involved in this project. Moreover, the wording of the quiz and questionnaire questions might have led to different interpretations. Other methodological limitations involve inherent biases, such as response bias, confirmation bias, and observer bias may have influenced the results.

Universal conclusion regarding digital learning and its assessment cannot be made based on this study. The findings of this study are context specific to ForestBioFacts and should not be generalized into other context without further investigation.

# 4 Results and discussion

This section presents, interprets, and discusses the results from the quiz and the post-questionnaire. In each subchapter, both quiz and post-survey results are presented and then critically reviewed and discussed.

## 4.1 Learning outcomes

As stated in the methods (see section 3.2) only Group 1 (G1) were provided with specific learning outcomes. Among these participants, 60% (three out of five) reported reading them, whilst the remaining 40% (two out of five) did not read the provided learning outcomes (see Table 8). Additionally, the post-questionnaire results show that participants who read the learning outcomes also felt like the given learning outcomes had a positive influence on their study approaches. Whereas the 40% who did not read them, felt the opposite. Furthermore, despite not everyone reading the learning outcomes, there was a unanimous agreement among all participants in both groups on their importance in ensuring successful learning (see Table 8).

Table 8. Participant engagement with learning outcomes and their perceived importance

| **Participants** | **Reviewed the learning outcomes** | **Read the FBF pre-materials** | **Learning outcomes deemed important** |
|---|---|---|---|
| Participant 1 (G1) | Yes | Yes | Yes |
| Participant 2 (G1) | No | Yes | Yes |
| Participant 3 (G1) | Yes | Yes | Yes |
| Participant 4 (G1) | No | No | Yes |
| Participant 5 (G1) | Yes | Yes | Yes |
| Participant 6 (G2) | Not given | Yes | Yes |
| Participant 7 (G2) | Not given | No | Yes |
| Participant 8 (G2) | Not given | No | Yes |
| Participant 9 (G2) | Not given | No | Yes |
| Participant 10 (G2) | Not given | No | Yes |

The quiz results indicate distinct differences between the two groups regarding the pre-materials. In Group 1, 80% of the participants (four out of five) had read the pre-materials sent via email two days before the testing day. As opposed to in Group 2 (G2), a similar majority of 80% (four out of five), did not review the pre-materials. The average rates of correct answers for Group 1 and Group 2 were 96.22% and 89.67%, respectively. In Tables 9 & 10, it can be seen that majority of participants in Group 1 had a higher number of correct responses compared to Group 2.

Table 9. Number of correct responses and percentage scores for Group 1 participants.

| **Group 1** | **Correct answers** | **Score (%)** |
|---|---|---|
| Participant 1 | 19/19 | 100 |
| Participant 2 | 19/19 | 100 |
| Participant 3 | 18.5/19 | 97.2 |
| Participant 4 | 18.6/19 | 97.9 |
| Participant 5 | 16.3/19 | 86.0 |
| **Average** | **18.3/19** | **96.2** |

Table 10. Number of correct responses and percentage scores for Group 2 participants.

| **Group 2** | **Correct answers** | **Score (%)** |
|---|---|---|
| Participant 6 | 18.6/19 | 97.9 |
| Participant 7 | 17.7/19 | 93.0 |
| Participant 8 | 16.9/19 | 89.3 |
| Participant 9 | 16.4/19 | 86.1 |
| Participant 10 | 15.6/19 | 82.3 |
| **Average** | **17.0/19** | **89.7** |

### 4.1.1 Discussion

In light of the findings, it can be stated that learning outcomes have various effects, ranging from increasing learning motivation to improving academic performance. The key findings of the impact of LOs are summarized in Table 11.

Table 11. Pros and cons of learning outcomes.

| Aspect | Pros | Cons |
|---|---|---|
| Learning outcomes | Increases motivation and improves academic performance | Not all students benefit equally from LOs |
| | Provided clear goals, aids students to focus on key topics | LOs alone do not directly result in better academic performance |
| | Encourages students to use effective study techniques | Might encourage surface learning if students focus only on what is expected |
| | Might reduce cognitive load, enabling students to focus on one thing at a time | |
| | Familiarizing with pre-materials helps student answer questions during the test | |

The possible effect of learning outcomes can be seen from the results of Group 1 who were given with learning outcomes and scored better on the quiz than Group2, who were not given the learning outcomes.

In addition to Group 1 having learning outcomes, majority within Group 1 also read them and felt that learning outcomes were useful for them. However, the participants who did not read the learning outcomes within Group 1 were just as successful as those participants who did read the learning outcomes within the same group. This suggests that giving only learning outcomes does not directly result in better academic results. The results also depend on the motivation and the learning goals of the participants. However, when comparing to Group 2 without learning outcomes, Group 1 had overall better results.

The impacts and the importance of learning outcomes are confirmed by research. Studies show that clear learning outcomes can increase students' motivation and encourage them to use more effective study techniques (Ambrose et al., 2010). By defining what needs to be learned, LOs provide students with clear goals. This guides them to concentrate on key topics that educators find most critical. As a results, students are more likely to focus on relevant information, resulting in more effective learning. The feedback from the post-questionnaire aligns with this, further confirming the benefits of well-articulated LOs.

All the participants from both groups, agreed that learning outcomes are crucial. They highlighted that clear and well-articulated LOs point out the most important and relevant topics to concentrate on. Some mentioned that effective learning outcomes can also motivate students. Furthermore, they noted the importance of learning outcomes in situations where study time is limited. In this thesis, the limited 60 minutes to finish the quiz was more than enough, since the participants submitted the quiz sooner than expected. With well-established LOs, students can quickly identify the key topics, making it easier in planning a study schedules.

Besides helping students better and increasing motivation, which may explain the success of Group 1, LOs might also reduce cognitive load. Ambrose et al. (2010), describe cognitive load as the total demand a task places on information processing. If the demand is too high, it can leave people unable to pay attention or use their cognitive resources efficiently. In this study, the provided pre-materials were manageable and not overwhelming, ensuring there was not too much to read. This allowed the participants to focus on one thing at a time, effectively reducing the possible cognitive load.

The study also found that reading both the learning outcomes and pre-materials might lead to better quiz results. In this research, which used an open-book exam format, getting to familiarise the materials in advance made it easier for students to answer the questions during the test. Whereas, attempting to read the materials for the first time during the quiz could increase stress as they might spend too much time searching for answers instead of applying what they already know. This is consistent with the results that show that Group 1 who received LOs and predominantly reviewed both the learning outcomes and the pre-materials, scored higher on average on the quiz.

## 4.2 AI vs. human-made questions

In the quiz, participants generally performed better on the human-made questions (Q12-Q19) compared to AI-based questions (Q1-Q11), as depicted in Figure 6. The human-made questions show a more consistent pattern, with results clustering around 80%. Thus, indicating a greater stability in participant responses. In contrast, the success rates for AI-based questions varied more, ranging from 55% to 100%. When comparing human-made questions and AI-generated questions, the quiz results depicted also in Figure 6, show that participants demonstrated a better skill with human-made questions, achieving a higher correct answer rate of 84%, whereas the success rate for AI-generated questions is 76%.

During the post-survey phase, the participants provided feedback on the structure and characteristics of both AI-generated (questions 1-11) and human-made (12-19) questions. The survey results indicate a preference for the human-made questions. For instance, 70% of the respondents reported that questions 12-19 more accurately reflected the pre-material content and were better structured compared to the AI-generated questions.

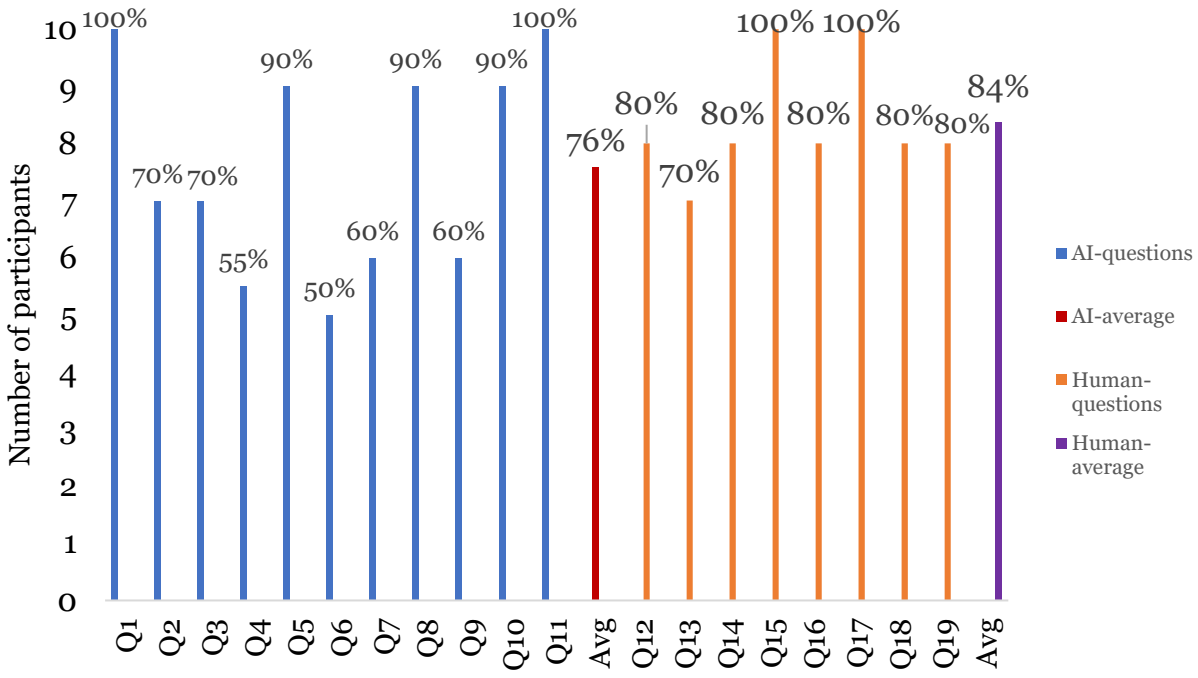


Figure 6. Percentage of correct answers per question. Orange illustrates AI-generated questions (Q1-Q11), whereas blue illustrates human-made questions (Q12-Q19). Dark purple illustrates the average correct answer rate

for human-made questions and dark red depicts the average success rate for AI-generated questions.

Based on the results of the survey (see Figure 7), 70% of respondent indicated that the majority of human-made questions were better structured. Additionally, two respondents (20%) believed that only human-made questions were structured effectively, while one participant (10%) remained neutral on this matter.

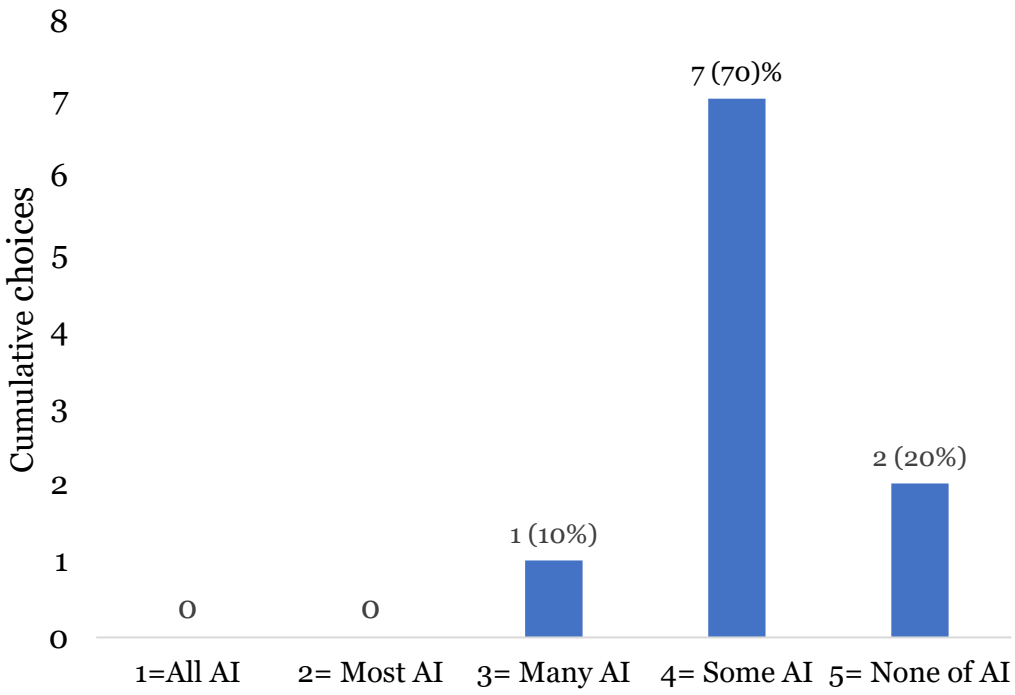


Figure 7. Survey results to the question “Which questions were structured better?”

In the survey, a majority (50%) reported that most of the AI-based questions were confusing. Additionally, three participants (30%) found that some AI-generated questions were confusing, whereas one respondent (10%) indicated that none of AI-generated questions were confusing. Only one participant (10%) remained neutral. The results can be seen in Figure 8.

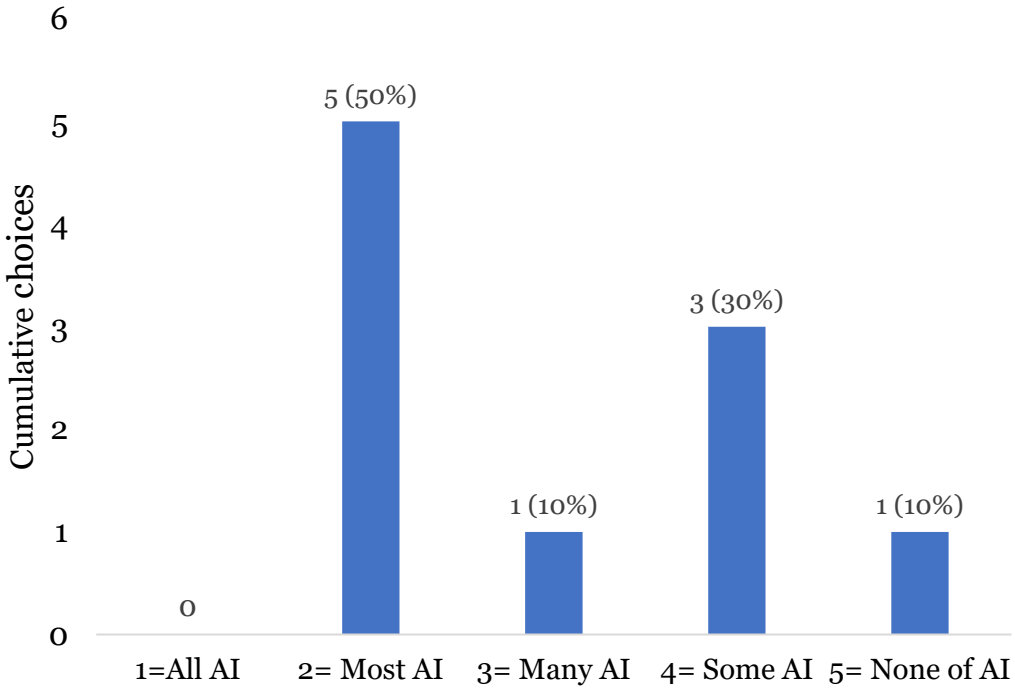


Figure 8. Survey results to the question “Which questions were confusing?”

According to the post-questionnaire results (Figure 9), 50% of the respondents, found that the majority of the human-made questions were easily understood. In contrast, two participants (20%) expressed that most of the AI-generated questions were easily understood. Additionally, one participant (10%) indicated that all of AI-generated questions were easily understood, whereas another participant (10%) said that all of human-made questions were comprehensible. Only one respondent, stayed neutral regarding this question.

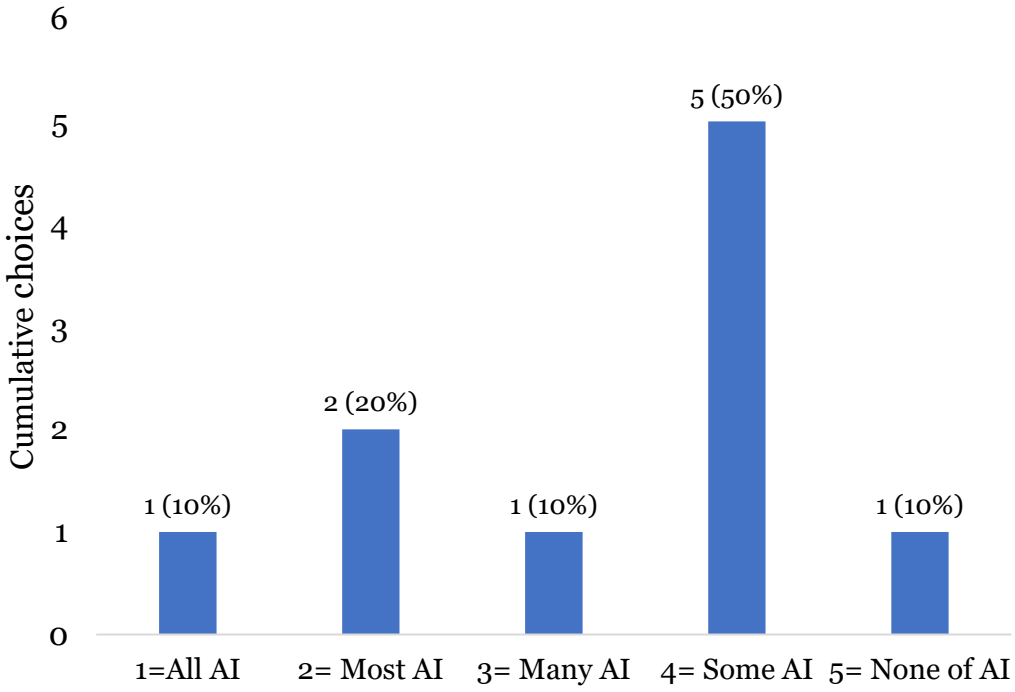


Figure 9. Survey results on the question "Which questions were easily understood?"

As illustrated in Figure 10, 50% of the respondents reported that majority of the human-made questions sounded more natural compared to those AI-generated questions. Additionally, two participants (20%), expressed that only human-made questions sounded more natural. In contrast, one participant (10%) felt that the majority of AI-generated questions had a more natural tone. Furthermore, 20% remained neutral on this matter.

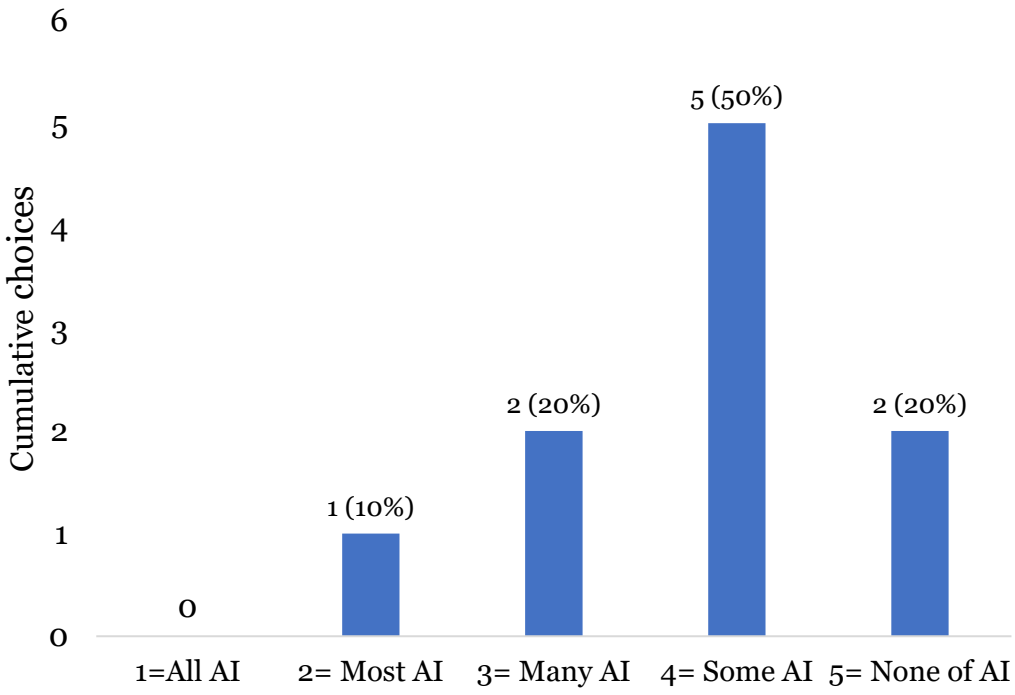


Figure 10. Survey results on the question "Which questions sounded more natural?"

In the post-questionnaire results (see Figure 11.), 50% of the respondents showed a preference for the majority of the human-made question, while 40% preferred exclusively human-made questions over those generated by AI. Only one participant (10%) stayed neutral in this comparison.

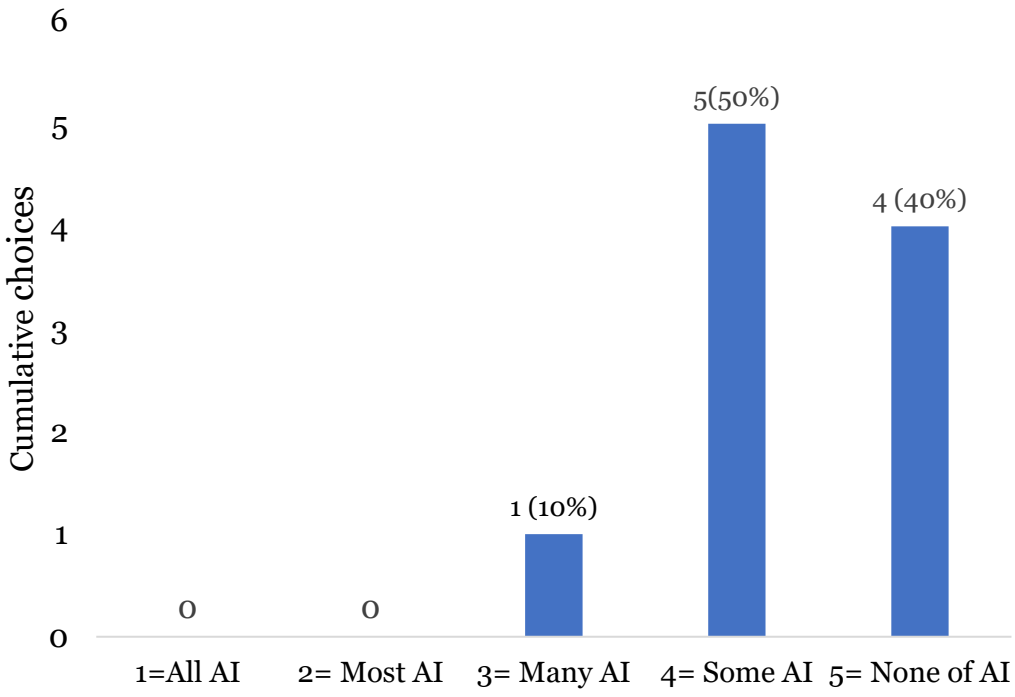


Figure 11. Survey results on the question "Which questions did you prefer?"

As depicted in Figure 12, 40% of the respondents indicated that the majority of the human-made questions were relevant to the topics covered in the given pre-materials. Conversely, 30% expressed that majority of the AI-generated questions were more relevant. The remaining 30% of the participants remained neutral on this matter.

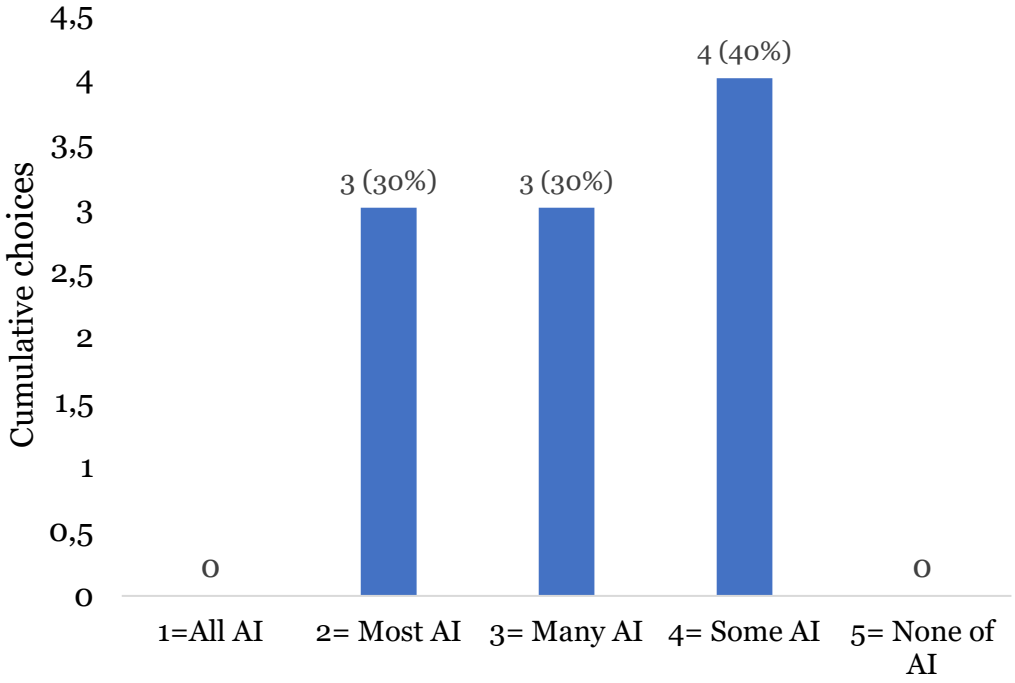


Figure 12. Survey results on the question "Which questions were relevant to the topic?"

Regarding the ease of answering the questions, there was an even split among participants: 50% found questions 1-11 easier to answer, while the other 50% preferred questions 12-19. In the feedback session following the post-questionnaire submission, the question “Do you think any questions were generated by AI”, left room for interpretation. Despite 50% of participants initially stating their suspicions that AI generated some questions, feedback revealed a misunderstanding of the question rather than actual suspicion. During the test no-one suspected that AI was used – they thought of AI only after seeing the questions about AI use. Moreover, when specifically asked to identify the AI-generated questions, 90% correctly identified the questions 1-11. University Lecturer who assisted in making questions has decades of experience in teaching. The lecturer also read the AI-created questions and was happy with them.

### 4.2.1 Discussion

The study suggests that the participants generally scored higher on human-made questions, compared to the AI-generated questions, with a slight difference in correct answer rates. However the difference wasn't statistically significant. Additionally, it is evident that participants expressed a clear preference for human-made questions over those generated by AI. This preference is due to various perceived characteristics. One way to explain this preference, is by examining the materials that were used to create both the human-made and AI-based questions. The key findings of the pros and cons of human-made and AI-generated questions are summarised in Table 12.

Table 12. The key findings of AI-generated and human-made questions.

| **Questions** | **Pros** | **Cons** |
|---|---|---|
| AI-generated | Can create questions on various topics due to extensive pre-training on a wide range of data | Might emphasize irrelevant details if not well-instructed |
| | Credible and human-like results, showing potential for use as assistance in educational environments | Can occasionally be less clear and a bit difficult to understand |
| | Efficient for generating a large volume of questions quickly | Quality of the questions depends significantly on used input materials and prompts |
| | Consistent format and style, thus useful for standardised testing | |
| Human-made | Clearer, easier to understand and more relevant to the topics of the quiz | Creating questions can be significantly more time-consuming and labour-intensive compared to AI |
| | Aligns better with the outcomes intended for the quiz | More vulnerable to human error |

As mentioned in the Methods section, (see section 3.1.2) the human-made questions (questions 12-19) were based on the articles around the licensed Natural fibre products theme. The articles under the theme were notably more informative and educational, providing detailed insight and knowledge to users. They contained a wide range of information regarding the different converting techniques of paper and board. Whereas the materials in the AI-generated questions (questions 1-11), were drawn from articles around "Introduction to forest-based bioeconomy", intended as an introductory content for the FBF, available for all users. These articles were designed to provide a general overview rather than in-depth analysis, aiming to familiarize readers with the broad concepts of the forest-based bioeconomy. Therefore, the role of the type of materials used in generating questions using AI is significant, since in this thesis AI creates questions based on the input material it was provided with. However, GenAI can also independently create questions on various topics without any immediate input due to its extensive pre-training on wide range of data (OpenAI, Privacy policy 2024).

If the material is written too broadly or it does not necessarily reflect the LOs, consequently the generated questions could also be of poor quality and relevance, confirmed by research (Kic-Dgras & Kılıçkaya, 2024). This is also consistent with the findings of this study. Since the licensed articles contained more informative material, it had a higher possibility to facilitate learning of the participants. This explains why the participants felt that AI-based questions sounded vaguer and more difficult to understand compared to the human-made questions, which were thought to be structured better, less confusing, more relevant to the topics of the quiz and easier to understand.

The vagueness and in some cases the complex structure of the questions generated by AI can be attributed not only to the quality of the materials used but also to ChatGPT itself. ChatGPT does not necessarily understand the objectives and the outcomes behind the questions. In a study conducted by Lee et al., 2023, they highlight the importance of the quality and structure of the prompts used. The study and the feedback confirm that ChatGPT might emphasize irrelevant details, instead of accurately pinpointing the main intent of the question. Thus, when generating questions using AI, it is important to structure and craft effective prompts that highlight the aim and the learning outcomes behind the questions.

In addition to highlighting the outcomes, it is also important to give a detailed instruction (Ekin, 2023). For instance, in this study, instead of giving the prompts detailed in Table 6, it might have been better to add more parameters, like setting the context of the questions. For example, by

rephrasing the one of the prompts the following way: “Based on the text I have provided for you, can you give me X multiple choice questions for me with one correct answer. The purpose of the questions is to use it in an online quiz where intended outcome of the text is for the student to be able to identify the benefits of continuous cover forestry methods compared to traditional clear-cutting practices.”. This way, the generated outcome might have been more accurate and relevant. A well-engineered and crafted prompt can significantly improve the quality and the relevance of the ChatGPT’s output, in contrast poorly phrased prompt, may lead to unsatisfactory results. This way, it is possible to minimise the vagueness and complexity of the questions. These factors might suggest why participants not only achieved higher scores on human-made questions but also preferred them over AI-based questions.

It is important to acknowledge the importance of constructing the questions in the post-survey to eliminate the possibility of misinterpretation. For instance, the question “Do you think any questions were generated by AI?” should have instead been rephrased as “During the quiz, did you think any questions were generated by AI?”. Moreover, this particular question also introduced bias with participants assuming that AI was involved despite not having any suspicions during the quiz. These insights suggest that the AI-generated questions were credible and thus in some sense human-like since they did not raise suspicion during the quiz itself. Indicating a big potential to explore the utilisation of GenAI as assistance in educational environments. However, due to the bias, the question apparently guided the respondents’ answers and therefore reliable conclusions cannot be drawn from the results of the question.

## 4.3 Question formats

When studying participants performance across different question types in the quiz, the results indicate a high level of accuracy for true/false, open-ended and match the word with the figure questions. As illustrated in Figure 13, correct response rates for open-ended questions ranged from 55% to 100%, MCQs varied from 50% to 80%, true/false questions showed 80% to 90% correctness. Video-based questions had a wider range of 60% to 100% and match the word with the right figure questions had a total success rate of 100%.

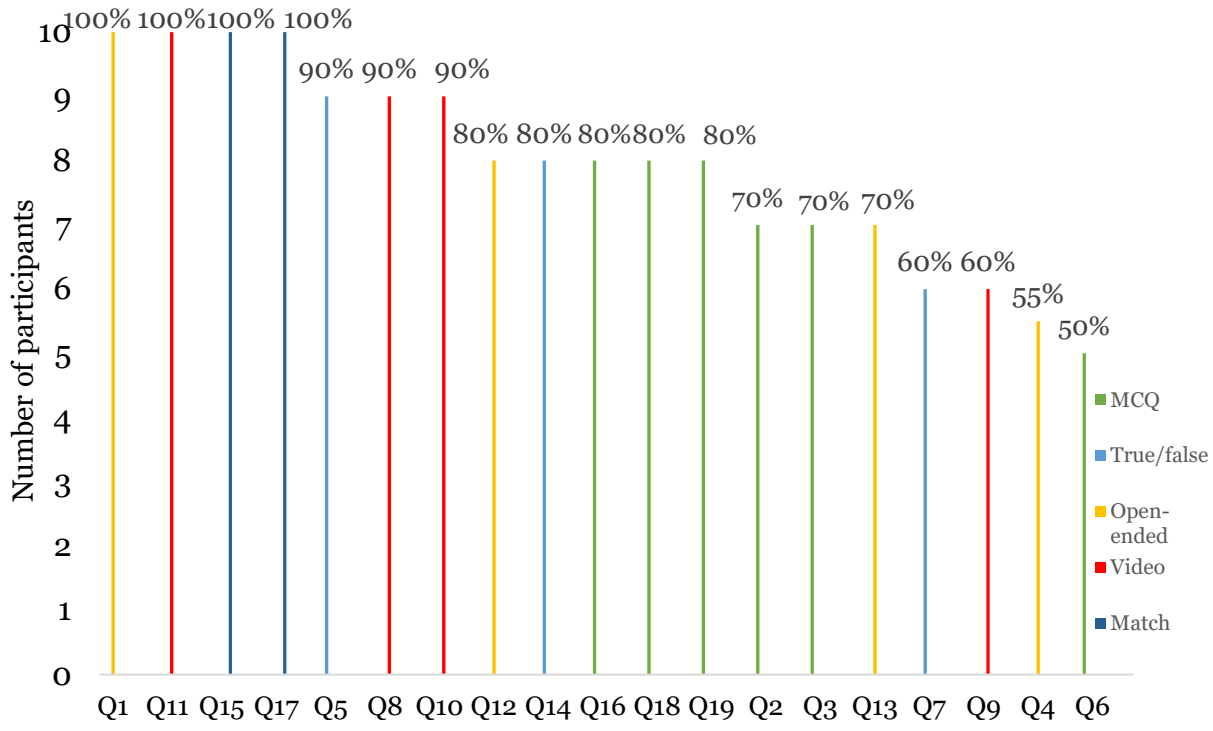


Figure 13. Distribution of correct responses rates by question types across all quiz questions. Each bar representing the proportion of participants who answered a particular question correctly.

The three question types with the highest average scores were match the word with the right figure at 100%, video-based questions at 85% and true/false questions at approximately 76.7%, as shown in Figure 14. Nevertheless, the difference in the average correctness rates for open-ended questions (76.4%), true/false (76.7%) and MCQs (71.7%) were relatively low.

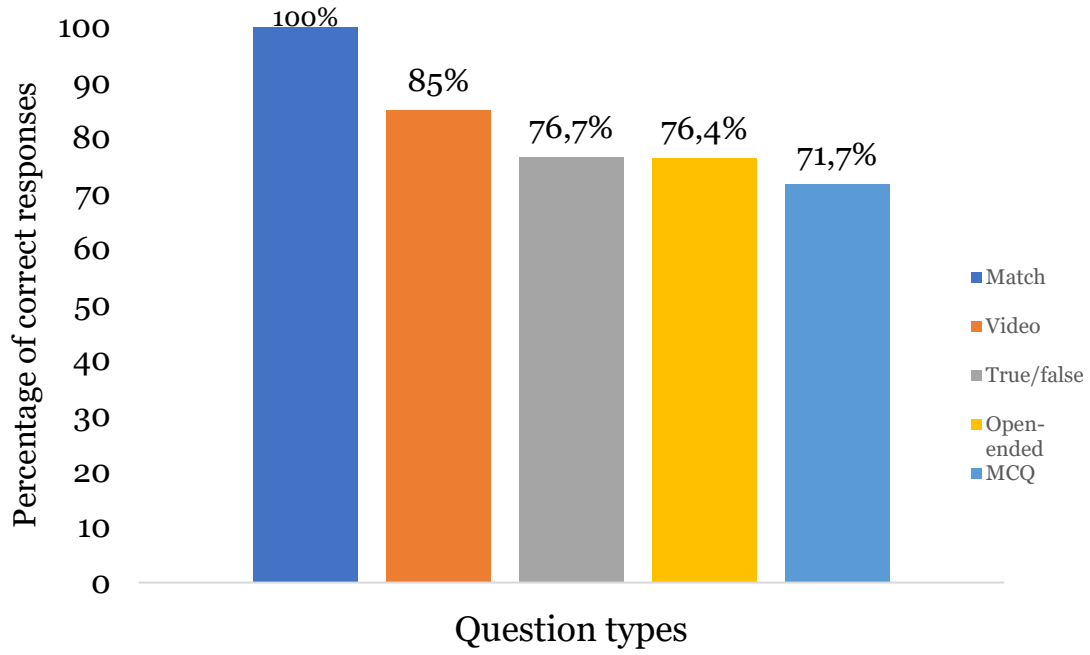


Figure 14. Overall average percentage of correct responses by question type.

As shown in Figure 15, the survey indicates that the top three types of questions that respondents found most challenging were MCQ, open-ended and video-based questions. The majority (60%), reported that open-ended questions were the most difficult. Followed by video-based questions receiving 40% of the votes for difficulty, while MCQs were ranked third, cited by 30% of respondents as challenging.

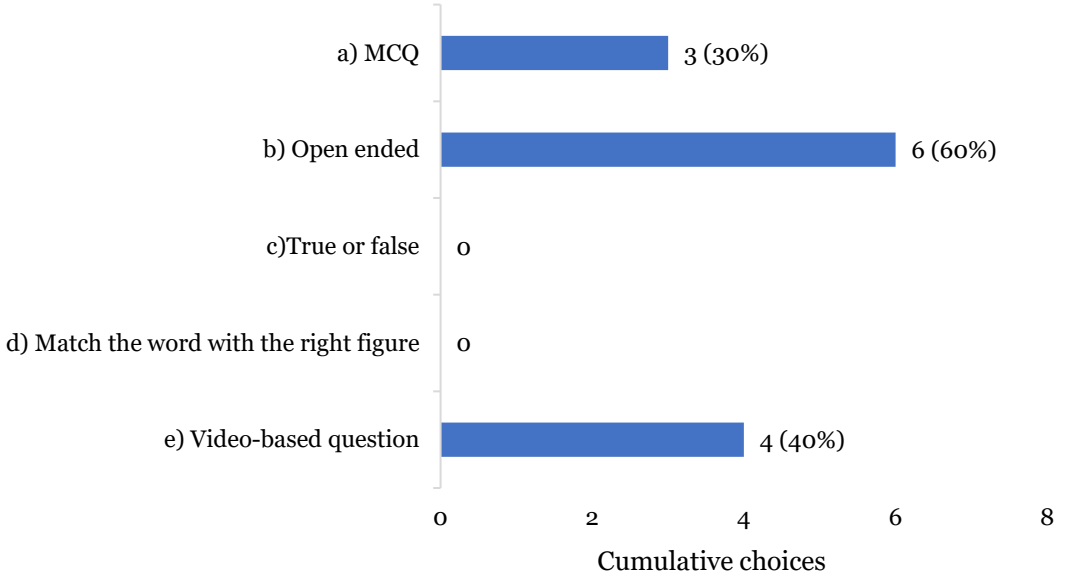


Figure 15. Survey results on the question "What type of questions did you find most difficult to answer to? You can choose more than one."

The post-questionnaire results, highlighted in Figure 16, indicate that respondents found true or false and matching word-to-figure to be the easiest, with both formats receiving 80% of the votes for ease of answering. MCQs were considered the second easiest, gaining 50% of the votes. Additionally, two participants (20%) felt confident in answering video-based questions, whereas only one respondent (10%) expressed open-ended questions as the easiest to answer.

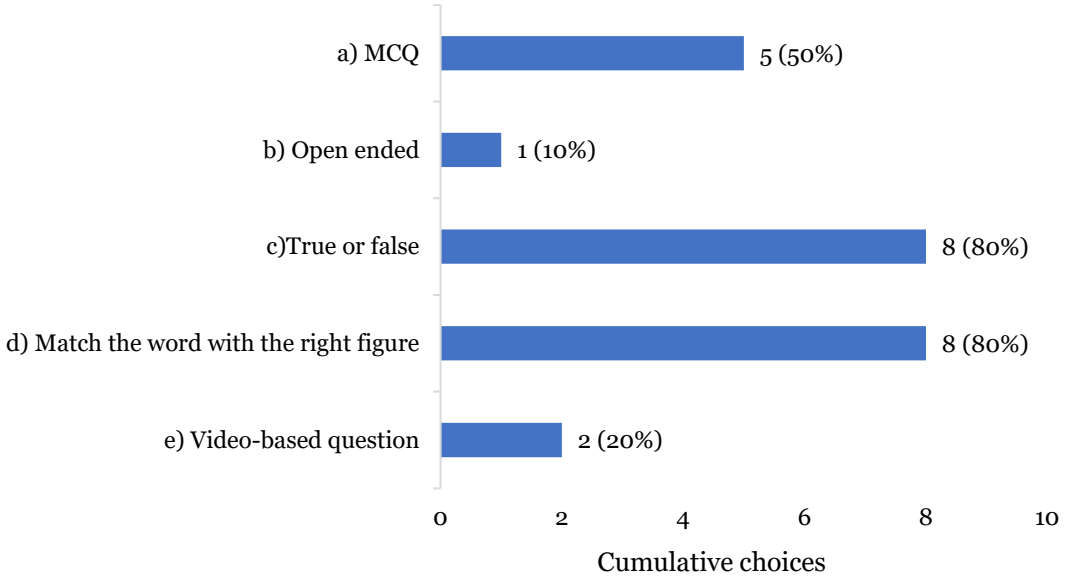


Figure 16. Survey results on the questions "What type of questions did you find easiest to answer to? You can choose more than one."

In this study, according to the post-survey results presented in Figure 17, respondents identified, MCQs and open-ended questions as the formats that best supported their learning. Both MCQs and open-ended questions received 70% of approval. True or false question types were considered the second most supportive, acquiring 40% of the votes, followed by video-based questions with 30%. Only two participants (20%) expressed that matching words with figures was most effective in supporting their learning.

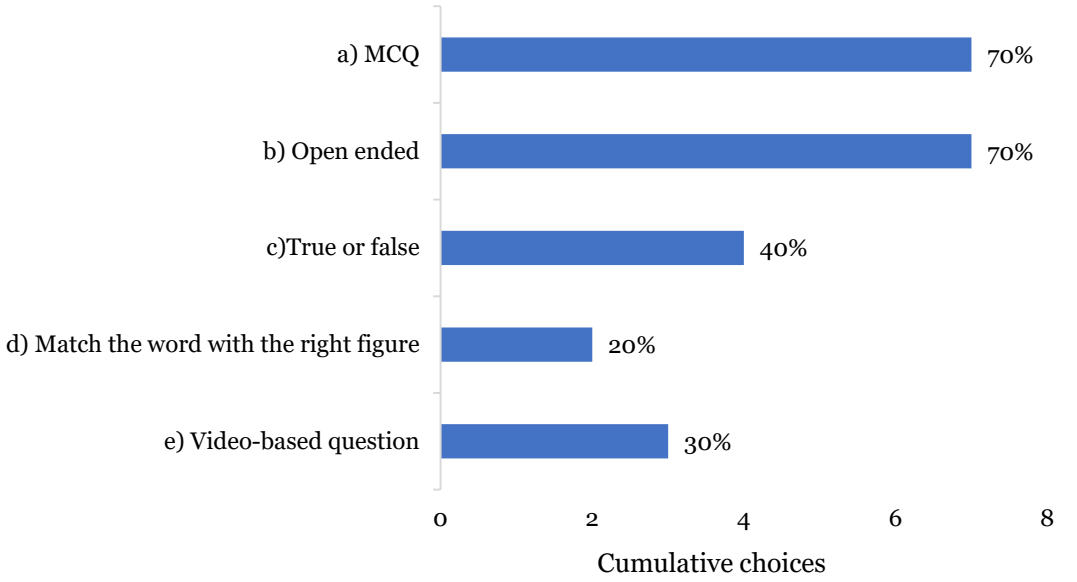


Figure 17. Survey results on the question "What type of questions do you think supports your learning the best? You can choose more than one."

The majority of the respondents (70%) reported their satisfaction with the number of questions in the quiz. Conversely, three participants (30%) preferred less questions. Results of the question is depicted in Figure 18.

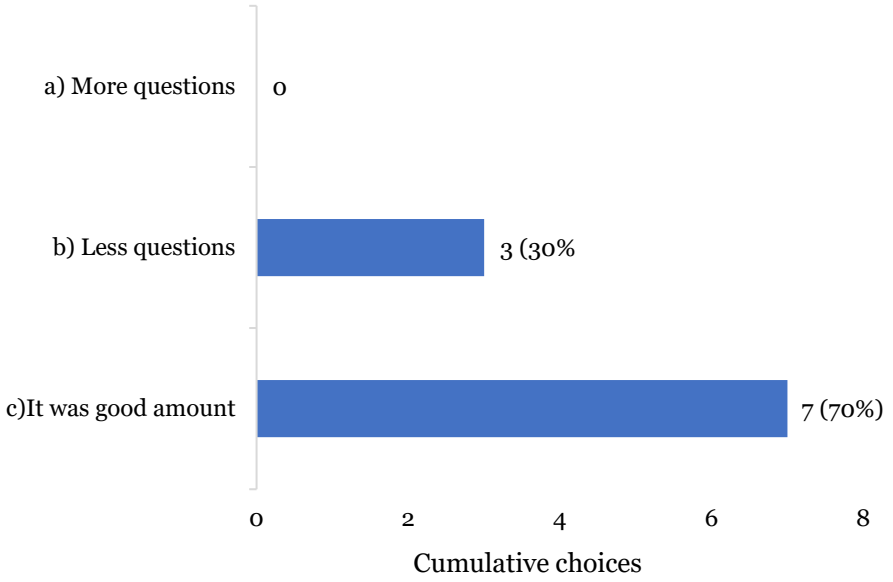


Figure 18. Survey results on the questions "Would you have preferred more or less questions?"

### 4.3.1 Discussion

The findings from both the quiz and post-survey highlight the preferences and challenges faced by participants concerning different question formats used in the quiz. The key findings of the survey are highlighted in Table 13.

Table 13. Key findings of the impact of question formats.

| **Question format** | **Pros** | **Cons** |
|---|---|---|
| Open-ended | Encourages critical thinking and thoughtfully constructed answers | Most challenging format for participants |
| | Acknowledged as significantly beneficial for learning. | Yields the second lowest percentage of correct responses |
| | Encourages deeper understanding and application of knowledge | Lack of objectivity in grading, leading to inconsistencies |
| MCQ | Preferred for their simplicity in answering | |
| | Reduces possibility of instructor bias | Scores the lowest in correctness, especially when multiple correct answers are possible |
| | Objective grading promotes consistency and reliability | More difficult to gain partial scores |
| | Allows for a broad coverage of content | Can encourage guessing when answering |
| True or false | Popular and straightforward format | May not sufficiently challenge participants, same as MCQs |
| | High performance scores | Can encourage guessing when answering |
| | Effective for testing specific knowledge | More difficult to gain partial scores |
| Match the word | Popular and straightforward format | Does not sufficiently challenge participants |
| | | Received less votes for being supportive of learning |
| Video-based | Engaging and informative | Lower rating in supporting learning, possibly due to unfamiliarity with the format |

The results indicate that participants found open-ended questions the most challenging. Research suggests that students often prefer MCQs to open-ended questions due to the reduced possibility of instructor bias and the relative ease of selecting the correct answer by elimination process (Tas & Minaz, 2019: Xu et al., 2016). Moreover, open-ended questions require a deeper understanding and applying the possibly obtained knowledge from the materials to be able to get full points.

The difficulty level of open-ended questions can be seen by their quiz scores, where open-ended questions yielded the second lowest percentage of correct responses. Despite their difficulty, these questions effectively encouraged participants to think critically and construct their answers thoughtfully, thereby supporting their learning experiences. This is further supported by the survey results, where most participants acknowledged open-ended questions as significantly beneficial to their learning.

Despite general preferences for MCQs due to their simplicity in answering, these questions scored the lowest in correctness. Possibly because incorrect answers in MCQs can lead to more significant point losses, especially when multiple correct answers are possible (Xu et al.,2016). The results of the quiz show, that the participants likely answered incorrectly in MCQs with multiple correct answers. These findings likely explain why the average correct response rates for MCQs are the lowest among the question types. Nonetheless, the survey indicated a strong preference for MCQs as supportive of learning, similar to open-ended questions.

Grading differences between question formats might also influence perceptions. For instance, open-ended questions lack objectivity in grading, which can lead to inconsistencies. Conversely, objective nature of MCQs grading promotes consistency, enhancing their reliability (Xu et al., 2016). However, this did not necessarily lead to higher performance scores for MCQs compared to open-ended questions, despite participants considering open-ended questions being more difficult than MCQs.

True or false and “match the word with the figure” questions also demonstrated popularity and high-performance scores. However, their straightforward nature may not sufficiently challenge the participants. This likely explains why they received less votes as being supportive for learning. Nonetheless, true or false questions can be designed to effectively test specific knowledge.

Video-based questions, while effective, were seen as the second most challenging type. Despite this percentage of correct answers to video

questions was high. Potentially due to their infrequent use and the participants' unfamiliarity with the format compared to the other question formats used in this study. This perception aligns with their lower rating in supporting learning.

According to relevant research (Kitazawa et al., 2016), the suitable number of questions in a quiz is typically around 15. However, based on the findings of the post-survey, this range seems slightly excessive and overwhelming when applied to each article. Therefore, considering both research and post-questionnaire feedback, a maximum of 10 questions per article seems to be a reasonable middle ground. Naturally, the number of questions should also be relative to the length of the used materials, and it is important to consider the respondents' experiences (Krosnick & Presser, 2010).

# 5 Conclusions

This final section concludes the thesis. First, key conclusions are presented. Then, suggested future lines of enquiry are presented.

## 5.1 Key conclusions

The main objective of this thesis was to explore the efficiency of digital learning environments (DLEs) by assessing the success of learning. Furthermore, the aim was to study the impact of learning outcomes (LOs), question formats and the usability of generative artificial intelligence (GenAI) in generating questions to enhance learning. Through extensive analysis of existing literature, quiz and a post-survey, the research objectives were addressed.

Essentially, DLEs can be seen as the platform that supports and enables all aspects of digital learning. DLEs make it possible to deliver, manage and enhance learning processes using both electronic devices and the internet. The use of DLEs is encouraged by professionals firstly for having the potential to enhance the effectiveness and accessibility of teaching and learning. Secondly, in an increasingly digitalized society, learning and education need to embrace digital platforms.

This thesis offers tools to ensure the effectiveness of DLEs using ForestBioFacts (FBF) as an example DLE. The results of the study suggest that LOs and question formats have an impact in improving learning. For instance, well-articulated and clearly written LOs, point out the most important and relevant topics to concentrate on. Additionally, LOs can reduce cognitive load and increase motivations, thus enhancing learning.

In addition to LOs, question formats can also affect the learning process. Many quiz takers prefer multiple-choice questions (MCQs), true or false and matching questions over open-ended questions. Compared to open-ended questions, they are considered easier to answer. Unlike open-ended questions, they are easier to grade and due to objectivity, it has less inconsistencies in grading. Whereas open-ended questions are vulnerable both to instructor bias and inconsistent grading, putting the student in an unfair position. Matching questions on the other hand are considered to be too straightforward and not necessarily as beneficial for learning compared to MCQs, true or false and open-ended questions. Therefore, based on the results of this study, it is recommended to use only MCQs and true or false question in further development of FBF. Open-ended questions are not recommended in this study since it will take too much resources to create and

grade high quality questions. Moreover, based on the findings of this study and research, it is recommended to create 10 quiz questions for each article at the end of each module in FBF. However, it should be noted that the number of questions should also be relative to the length of the article.

In addition to recommending the use of well-articulated, clear LOs and MCQs and true or false questions, it is efficient to use GenAI in creating those questions. The use of GenAI takes a significantly less time and resources to create questions compared to human-made questions. In addition to saving resources, the results of this thesis show positive and encouraging results on the quality and use of GenAI in generating questions. Even though the results indicate the preference for human-made questions, the use of AI-generated questions was not obvious, and nobody realised to suspect it in the process of doing the quiz. Many of the reasons that likely explain the preference of human-made questions over AI-generated questions can be eliminated by the efficient use of prompts and by use the same quality of source materials.

## 5.2 Suggestions for further research

DLEs were shown to be a valuable tool in facilitating an effective and successful learning process. However, it should be acknowledged that the successful implementation of DLEs is dependent upon many factors. Based on this study, the use of GenAI could be further improved. For instance, by efficient prompt engineering. To obtain the full potential of GenAI, it is recommended to describe the context of the prompt. First by adding the learning outcomes of the provided material, then by giving a detailed description of the type of questions, number of questions and inclusion of distractors. For instance, in MCQs, it is recommended to instruct the AI on how to create plausible distractors. They should be realistic and close enough to the correct answer to be challenging but still clearly distinguishable with proper understanding. Additionally, to avoid repetition and too similar questions, it is recommended to add in the prompt to generate questions that differ in content to avoid predictability. Lastly, if wanted, it is also possible to specify the desired difficulty level of the questions, so it aligns with the target group's knowledge level (e.g. beginner, intermediate, advanced).

To further improve prompts, it is important to select materials of which their content do not differ too much from each other quality wise. It is recommended to use materials that both contain equally as much educational/informative content instead of using contents that some are meant for introductory reasons and others for educational reasons. This way, the possibility of AI generating questions that sound too vague, complex, or irrelevant are reduced.

When conducting a post-survey either quantitative or qualitative, it is important to avoid questions that are easily misinterpreted. This way it is possible to obtain data that is easily analysable, and it also increases validity and reliability of the results.
Finally, one limitation of the results is the small sample size. With larger sample size, it would have increased more the reliability and validity of the quiz results. However, due to time and resource constraints in the thesis, the research was to be conducted with 10 participants.

This thesis will contribute to the development of DLEs, such as FBF digital learning environment. The results from this study support the continued exploration of GenAI as a tool for advancing FBF projects. It is important to acknowledge that technologies like ChatGPT are continuously enhancing and it may perform beyond what was observed in this thesis. Nonetheless, this study highlighted the significant impact and potential of LOs and GenAI in facilitating learning and making DLEs more efficient and successful.

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# Appendix I. Examples of different question formats in front-end and back-end

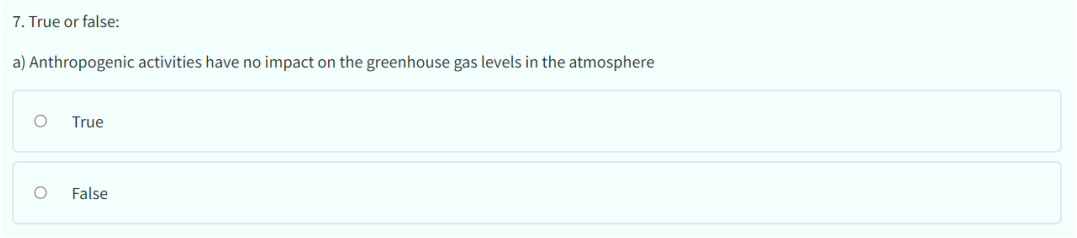


Figure 1a. An example of a front-end single choice question used in the quiz.

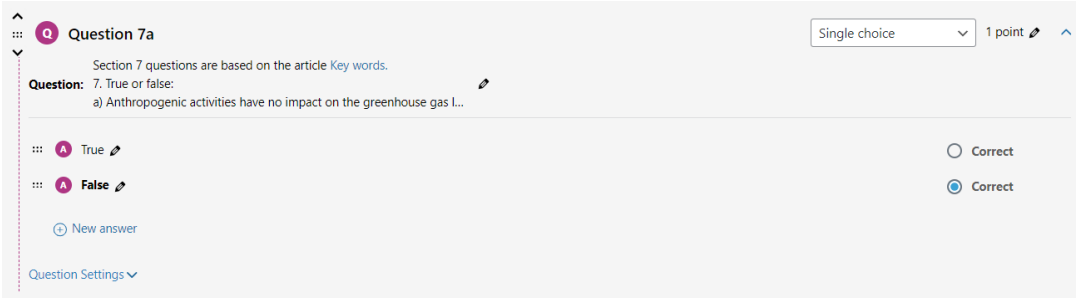


Figure 1b. An example of a back-end single choice question used in the quiz.

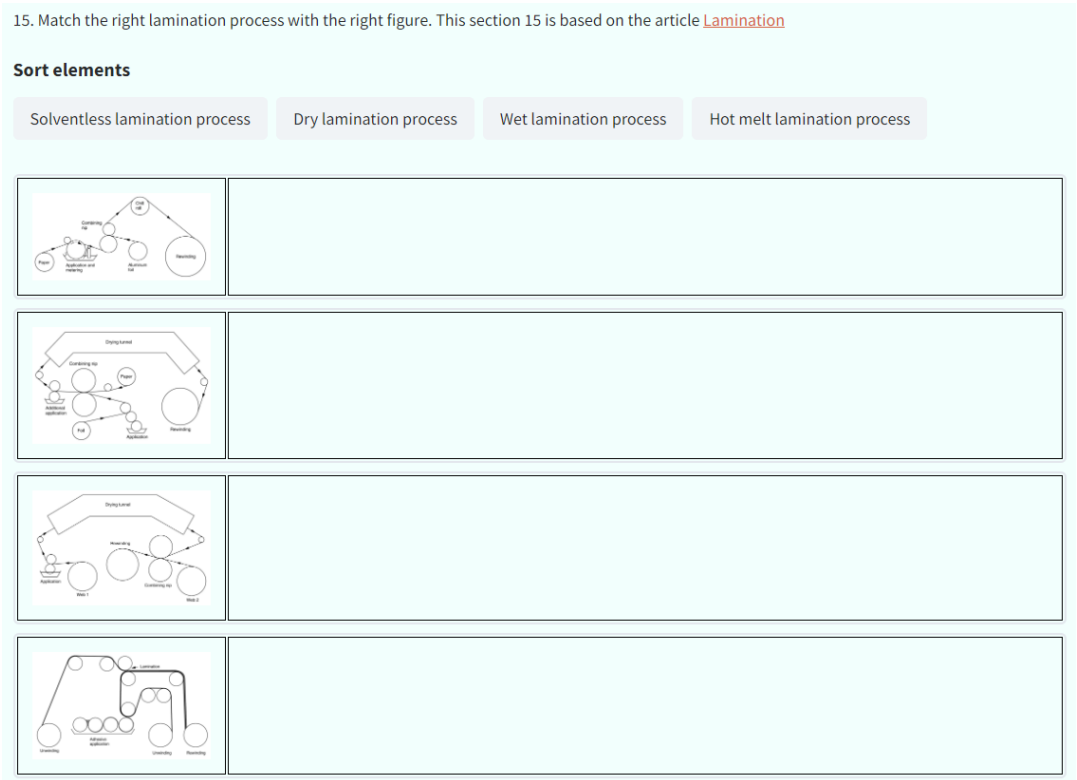

Figure 2a. An example of a front-end matrix sorting choice question.

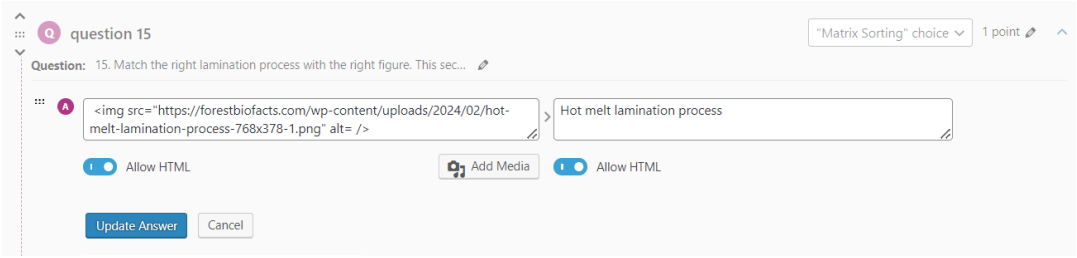


Figure 2b. An example of a back-end matrix sorting question.

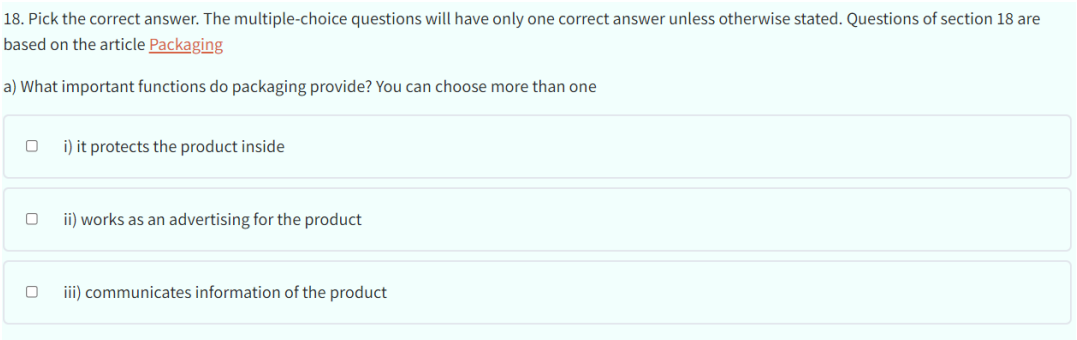


Figure 3a. An example of a front-end MCQ used in the quiz.

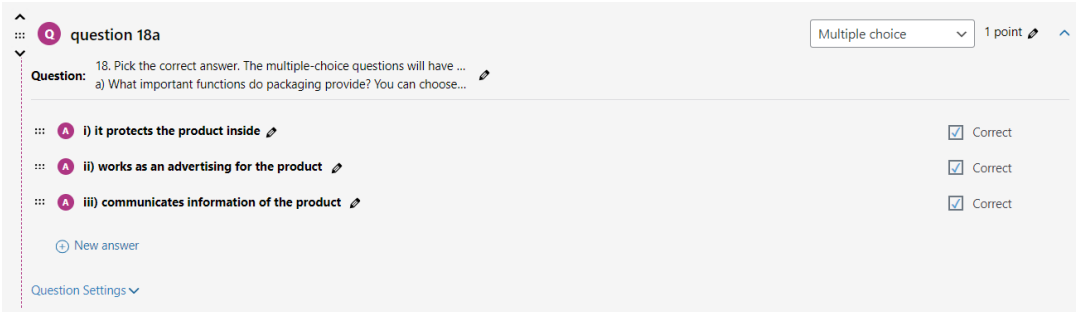


Figure 3b. An example of a back-end MCQ used in the quiz.

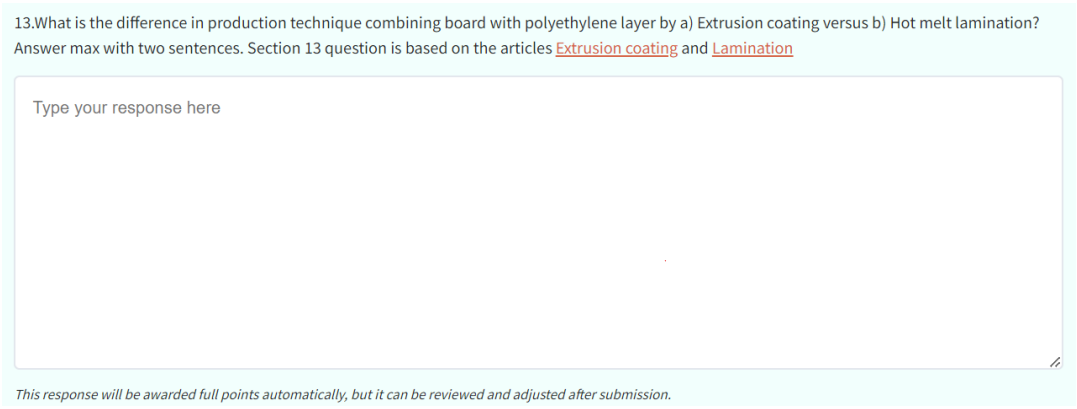


Figure 4a. An example of a front-end Essay/Open Answer question used in the quiz.

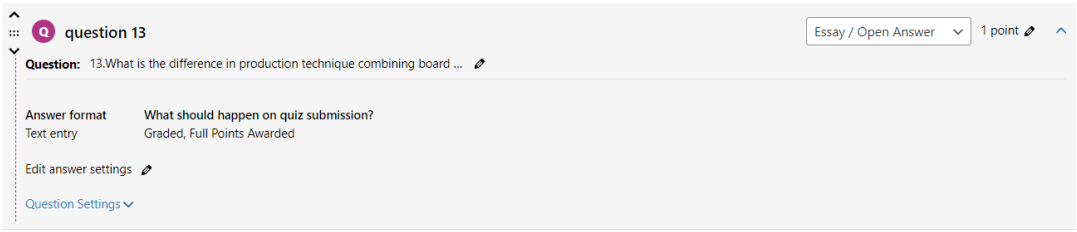


Figure 4b. an example of a back-end Essay/Open Answer question used in the quiz.

# Appendix II. Learning outcomes for Group 1

**The bioeconomy is humankind's greatest opportunity:**

- By the end of this short module, participants will be able to identify the benefits of continuous cover forestry methods compared to traditional clear-cutting practices.
- By the end this short module, participants will be able to describe the different roles of forest bioeconomy:
    I. the role of forests as carbon sinks and stocks

**Carbon cycle and circular bioeconomy:**

- By the end of this short module, participants will be able to identify the benefits and roles of forest management on carbon storage.
- By the end of this module, participants will be able to name the main sources of raw materials for circular bioeconomy.

**Converting:**

- By the end of this short module, participants will be able to explain the main targets of board converting.

**Dispersion coating:**

- By the end of this short module, participants will be able to identify and explain the main features of the coating process in dispersion coating.
- By the end of this short module, participants will be able to identify the key properties of latexes used in dispersion coating.
- By the end of this module, participants will be able to describe the advantages of dispersion coating vs. extrusion coating.

**Lamination:**

- By the end of this short module, participants will be able to name a few different lamination processes.
- By the end of this short module, participants will be able to describe the basic principles of lamination.

**Extrusion coating:**

- By the end of this short module, participants will be able to describe the extrusion coating processes in basic level.

**Special coating and treatments:**

- By the end of this short module, participants will be able to summarize the main aims of surface treatments.

**Packaging:**

- By the end of this short module, participants will be able to describe the main functions of packaging.

**Closing of packages:**

- By the end of this short module, participants will be able to describe main package closing methods.

## Appendix III. Quiz questions

Did you read the pre-materials given to you before arriving to do this test?

a) Yes
b) No

1. What role do recycled materials play in the circular bioeconomy? Answer max with two sentences. (model answer **Recycled materials, such as paper, board products, textile products, and construction lumber, are essential in the circular bioeconomy serving as feedstocks and reducing the reliance on new materials.**
2. True or false:
    a. The primary source of new raw materials for the circular bioeconomy is the biological carbon cycle formed by the biosphere and the atmosphere.
        **i. true**
        ii. false
    b. In modern pulp mills, the main energy source is non-renewable fossil fuels
        i. true
        **ii. false**
    c. growing forests act as carbon sinks by accumulating carbon in trees through biosynthesis
        **i. true**
        ii. false
    d. the burning of fossil fuels creates an anthropogenic CO2 flux that has a natural counterpart with returns CO2 back to fossil deposits
        i. true
        **ii. false**
3. Pick the correct answer. The multiple-choice questions will have only on correct answer unless otherwise stated. Section 3 questions are based on article Carbon cycle and Circular bioeconomy.
    a) What role do growing forests play in the carbon cycle?

a. they act primarily as carbon emitters
**b. they function as carbon sinks, absorbing CO2**
c. they have no significant impact on the carbon cycle
d. they only release carbon into the atmosphere

b) What has been impact of effective forest management techniques on global carbon balance since 1900?

e. increased the cumulative loss in carbon storage due to timber harvesting
**f. reduced the cumulative loss in carbon storage due to timber harvesting**
g. had no significant impact on carbon storage
h. only affected the carbon storage in tropical forests

c) which materials are mentioned as being part of the circular bioeconomy's recycled raw materials? You can pick more than one.

**i. recycled paper**
**j. used textile products**
**k. construction lumber**
l. plastic bottle

4. Explain why continuous cover forestry is considered beneficial compared to conventional forestry methods. Answer max with two sentences. (**Model answer: continuous cover forestry allows for the growth of trees of different ages simultaneously, reducing the need for clearcutting and supporting biodiversity. This method also distributes income over shorter periods and can be more financially profitable due to lower silvicultural costs.)**
5. Section 5 questions are based on the article the bioeconomy is humankind's greatest opportunity.

   True or false:

   a. Wood is the main raw material of the forest bioeconomy because of its scarcity and low renewability
      i. true
      **ii. false**
   b. in Finland, about 20% of the total energy consumption is met by wood-based fuels
      **i. true**
      ii. false
   c. continuous cover forestry is a method that involves clearcutting entire forests and is not focused on sustainability
      i. true
      **ii. false**
   d. forests act as carbon sinks and help in sequestering carbon dioxide from the atmosphere
      **i. true**
      ii. false

e. the majority of Finland's forests are under government ownership and are not certified for sustainable forestry
    i. true
    **ii. false**

6. Pick the correct answer. The multiple-choice questions will have only one correct answer unless otherwise stated. Section 6 questions are based on the article The bioeconomy is humankind's greatest opportunity.
a) What is the main raw material of the forest bioeconomy?
    a. coal
    b. steel
    **c. wood**
    d. plastic

b) Which method of forestry is becoming more common alongside conventional periodic eve-aged forestry in Finland?
    e. Industrial farming
    **f. continuous cover forestry**
    g. urban forestation
    h. monoculture plantation

c) What are the benefits of using wood as a raw material in the forest bioeconomy? You can pick more than one.
    **i. it is rapidly renewable resource**
    **j. it replaces materials causing higher emissions**
    k. it is available only in tropical zones
    l. **it is versatile in different conversion processes**

d) What are the key aspects of sustainable forestry? You can pick more than one
    m. increasing carbon dioxide emissions
    **n. maintaining biodiversity**
    o. clearcutting without replanting
    **p. proper tending of forests**

e) What roles do forests play in combating climate change and supporting the bioeconomy? You can pick more than one.
    **q. acting as carbon stocks and carbon sinks**
    **r. providing renewable raw materials for industries**
    s. increasing urban areas for population growth
    **t. sequestering carbon through photosynthesis**

7. Section 7 questions are based on the article Key words
True or false:
    a. Anthropogenic activities have no impact on the greenhouse gas levels in the atmosphere
        i. true
        **ii. false**
    b. All bioplastics are biodegradable and can be composted
        i. true

    ii. **false**
c. The boreal forest zone covers about 15% of the continental area and is known for its high species diversity in undergrowth.
    i. true
    ii. **false**
d. continuous cover forestry involves clear-cutting large areas of forest to promote regeneration.
    i. true
    ii. **false**

Section 8 & 9 are based on the video by Heikki Hassi. The video can be found on the article The bioeconomy is humankind's greatest opportunity.

8. True or false. Forest products can substitute for fossil-based products and capture carbon dioxide released by human activities.
    a. **True**
    b. false
9. What are the two benefits of controlled usage of forest resources mentioned in the text?
    a. It can increase the land available for natural areas
    b. **Substituting for fossil-based products**
    c. **Preventing uncontrolled land usage changes, which are a source of carbon dioxide releases**
    d. exclusively focusing on the production of hygiene products

Section 10 & 11 are based on the video by Seppo Kellomäki. The video can be found under the article of The bioeconomy is humankind's greatest opportunity.

10. True or false. Building more wooden houses can help reduce carbon emissions by avoiding the use of concrete, known for its massive carbon emissions.
    a. **true**
    b. false
11. True or false. Forests are considered a non-renewable resource that cannot be used indefinitely.
    a. True
    b. **false**
12. What are the two advantages of Dispersion coating concerning recycling of coated board? Answer max with two sentences. (**Paper and board grades coated with barrier latexes are pulpable in a conventional pulper, so the broke can be slushed in a machine pulper and reused in the process, in many cases without any special treatment. Dispersion-coated package waste from waste paper collection receivers can in general be handled in the same way as other waste paper**.)
13. What is the difference in production technique combining board with polyethylene layer by a) Extrusion coating versus b) Hot melt lamination?

Answer max with two sentences. (**Extrusion coating is a process where a molten plastic is applied in film form onto a rapidly moving web and after the wax or hot melt is applied, the two webs are pressed together in the lamination nip and the wax or hot melt starts to cool.)**

Section 14 questions are based on the article Dispersion coating.

14. True or false:
    a. In dispersion coating latexes typically resemble the appearance of milk
        **i. true**
        ii. false
    b. Latexes used in dispersion coating are not water-bore emulsion polymers
        i. true
        **ii. false**
    c. Besides water and polymer, latexes in dispersion coating does not contain several additives and fillers
        i. true
        **ii. false**
15. Match the right lamination process with the right figure.
16. Pick the correct ones. The multiple-choice questions will have only one correct answer unless otherwise stated. Section 16 questions a & b are based on article Special coatings and treatments.
    a) In special coatings and treatments, surface treatments are used to:
        a. to decrease surface energy
        **b. to remove contaminants**
        **c. to remove weak boundary layers**
    b) Due to what reasons paper, polymers or paperboard rarely have the required surface properties?
        **a. incompatibility**
        b. high surface energy
        **c. chemical inertness**
    c) What treatment can be defined as ”the fourth state of matter”? Question 12c is based on article Surface treatment.
        a. Corona treatment
        b. flame treatment
        **c. plasma treatment**
17. Match the right coating process with the right figure.

18. Pick the correct answer. The multiple-choice questions will have only one correct answer unless otherwise stated. Questions of section 18 are based on the article Packaging.

a) What important functions do packaging provide? You can choose more than one.
   - **a. it protects the product inside**
   - **b. works as an advertising for the product**
   - **c. communicates information of the product**

b) what is the most common package printing method?
   - i) gravure printing
   - **j) flexo printing**
   - k) offset printing
   - l) digital printing

c) Why do cartons usually require varnishing?
   - a. to improve the barrier properties of the carton
   - **b. to protect the printed substrates against rubbing**
   - c. to protect the product from odour and light

19. Pick the correct answer. The multiple-choice questions will have only on correct answer unless otherwise stated. Section 19 questions are based on the article Closing of packages.

a) What ways can packages be closed? you can choose more than one
   - **a. sealing**
   - b. chemical ways
   - **c. mechanical ways**
   - **d. gluing**

b) What closing method is often used for extrusion coated materials?
   - **e. sealing**
   - f. gluing
   - g. clamps

c) What closing method is often used for folding cartons?
   - h. sealing
   - **i. gluing**
   - j. clamps

## Appendix IV. Post-questionnaire questions

1. Please state your first name.
2. What phase of your studies are you in?
    a. Bachelor's
    b. Master's
    c. PhD
    d. Working
3. a) Please compare questions from 1-11 with questions 12-19. Which questions were easier to answer?
    a. questions 1-11
    b. questions 12-19

    b) Which questions were reflecting better the contents of the articles?
    c. questions 1-11
    d. questions 12-19

    c) Which questions were better structured?
    e. questions 1-11
    f. questions 12-19
4. Do you think any questions were generated by AI?
    a. yes
    b. no
5. If yes, what made you suspect that? Please elaborate.
6. Which questions do you think were AI-generated?
    a. questions 1-11
    b. questions 12-19
7. Questions 1-11 were generated by AI based on the articles given in pre-materials (carbon cycle and circular bioeconomy and the bioeconomy is humankind's greatest opportunity). React to the following statements. 1=All AI, 2=Most AI, 3=Many AI, 4=Some AI, 5=None of AI

    a) Which questions were structured better?
    b) Which questions were confusing?
    c) Which questions were easily understood?
    d) Which questions sounded more natural?
    e) Which questions did you prefer?
    f) Which questions were relevant to the topic?

8. What type of questions did you find most difficult to answer to? you can choose more than one.
    a. multiple-choice
    b. open-ended
    c. true or false
    d. connect the word with the right picture

    e. questions related to videos
9. What type of questions did you find easiest to answer to? You can choose more than one.
    a. multiple-choice
    b. open-ended
    c. true or false
    d. connect the word with the right picture
    e. questions related to videos
10. What type of question do you think supports your learning the best? You can choose more than one.
    a. multiple-choice
    b. open-ended
    c. true or false
    d. connect the word with the right picture
    e. questions related to videos
11. In your pre-materials, you were possibly given specific learning outcomes. Did you read them?
    a. yes
    b. no
    c. I wasn't given learning outcomes
12. If you did read the learning outcomes, do you think it had any effect on the way you studied for this quiz?
    a. yes
    b. no
13. Do you think providing learning outcomes to the student is important to ensure the success of learning? Please elaborate.
14. Would you have preferred more or less questions?
    a. more questions
    b. less questions
    c. it was good amount
15. I have read the privacy policy and I accept it.
    a. I accept.