DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

# USABILITY EVALUATION OF A LEARNING MANAGEMENT SYSTEM WITH AXIOMATIC DESIGN

by

Ceylin ÜNAL

October, 2022
İZMİR

# USABILITY EVALUATION OF A LEARNING MANAGEMENT SYSTEM WITH AXIOMATIC DESIGN

**A Thesis Submitted to the**
**Graduate School of Natural and Applied Sciences of Dokuz Eylül University**
**In Partial Fulfillment of the Requirements for the Degree of Master of Science in Industrial Engineering, Industrial Engineering Program**


**by**
**Ceylin ÜNAL**



**October, 2022**
**İZMİR**

**M.Sc THESIS EXAMINATION RESULT FORM**

We have read the thesis entitled **"USABILITY EVALUATION OF A LEARNING MANAGEMENT SYSTEM WITH AXIOMATIC DESIGN"** completed by **CEYLİN ÜNAL** under supervision of **PROF.DR. ADİL BAYKASOĞLU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Prof. Dr. Adil BAYKASOĞLU

Supervisor

Asst. Prof Dr. Burcu FELEKOĞLU

(Jury Member)

Asst. Prof Dr. Esra EKİNCİ

(Jury Member)

Prof. Dr. Okan FISTIKOĞLU

Müdür

Fen Bilimleri Enstitüsü

## ACKNOWLEDGEMENTS

Firstly, I would like to thank to my supervisor Prof. Dr. Adil BAYKASOĞLU for his valuable ideas and contributions that helped me overcome challenges throughout my M.Sc. thesis. Thanks to him, I am not only completed my thesis, but also introduced analytical thinking approach into my life.

At the same time, I would like to thank Asst. Prof. Dr. Burcu FELEKOĞLU for her support and guidance from the very beginning of the thesis. I was able to overcome every difficulty I encountered easily with her knowledge, interest and encouragement.

Finally, I would like to thank all my friends and family for their support and belief along the way.

Ceylin ÜNAL

**USABILITY EVALUATION OF A LEARNING MANAGEMENT SYSTEM WITH AXIOMATIC DESIGN**

## ABSTRACT

With the disruption of face-to-face educations after the Covid-19 pandemic worldwide, the usage of Learning Management Systems (LMS) has become widespread. Various software products usually named as LMS, that provide distance education, are used by universities and various educational institutions. However, choosing an appropriate LMS is a complex Multiple Criteria Decision Making (MCDM) problem and has also gained importance over time. Within the scope of this problem, although usability evaluation of the LMS is used, there are not many studies in the literature in which the MCDM method is used and real life case studies are conducted. In this direction, perceived usability evaluation of the SAKAI-LMS, that is in use at an academic department is performed as a real life case study. An integrated MCDM model is created from the usability criteria based on the analyses of the related literature. A questionnaire is developed and directed to three types of system users, to evaluate these criteria's importance and levels of fulfillments by the system. The criteria weights are calculated via analytical hierarchy process and detailed statistical analyzes of the data obtained from the questionnaire is made. For LMS perceived usability evaluation, Axiomatic Design Procedure (ADP) is considered as a suitable MCDM method as it allows an easy approach to data fusion and setting performance targets for decision makers. It is concluded that the proposed ADP based approach is easy to apply to practical circumstances and able to quantify perceived usability of the existing SAKAI system.

**Keywords*:*** Learning Management Systems, Usability Evaluation, Axiomatic Design, Distance Learning, Multiple Criteria Decision Making

# BİR ÖĞRENME YÖNETİM SİSTEMİNİN AKSİYOMATİK TASARIM İLE KULLANILABİLİRLİK DEĞERLENDİRMESİ

## ÖZ

Dünya genelinde Covid-19 pandemisi sonrası yüz yüze eğitimlerin kesintiye uğraması ile Öğrenme Yönetim Sistemlerinin (ÖYS) kullanımı yaygınlaşmıştır. Üniversiteler ve çeşitli eğitim kurumları tarafından uzaktan eğitimi sağlayan ve genellikle ÖYS olarak adlandırılan çeşitli yazılım ürünleri kullanılmaktadır. Ancak, uygun bir ÖYS seçimi karmaşık bir Çok Kriterli Karar Verme (ÇKKV) problemi olmakla beraber zamanla önem de kazanmıştır. Bu problem kapsamında ÖYS'nin kullanılabilirlik değerlendirmesi kullanılsa da literatürde ÇKKV yönteminin kullanıldığı ve gerçek hayat vaka çalışmalarının yapıldığı çok fazla çalışma bulunmamaktadır. Bu doğrultuda bir akademik bölümde kullanılan SAKAI-ÖYS'nin algılanan kullanılabilirlik değerlendirmesi gerçek hayattan bir örnek olay olarak yapılmıştır. İlgili literatürün analizine dayalı olarak kullanılabilirlik kriterlerinden entegre bir ÇKKV modeli oluşturulmuştur. Bu kriterlerin önemini ve sistem tarafından yerine getirilme düzeylerini değerlendirmek için bir anket geliştirilmiş ve üç tür sistem kullanıcısına yönlendirilmiştir. Kriter ağırlıkları analitik hiyerarşi süreci ile hesaplanmış ve anketten elde edilen verilerin detaylı istatistiksel analizleri yapılmıştır. ÖYS algılanan kullanılabilirlik değerlendirmesinde Aksiyomatik Tasarım Prosedürü (ATP), veri birleştirme ve karar vericiler için performans hedefleri belirlemede kolay bir yaklaşım sağladığı için uygun bir ÇKKV yöntemi olarak kabul edilir. Önerilen ATP tabanlı yaklaşımın pratik koşullara uygulanmasının kolay olduğu ve mevcut SAKAI sisteminin algılanan kullanılabilirliğini ölçebildiği sonucuna varılmıştır.

**Anahtar kelimeler:** Öğrenme Yönetim Sistemi, Kullanılabilirlik Değerlendirmesi, Aksiyomatik Tasarım, Uzaktan Eğitim, Çok Kriterli Karar Verme

## CONTENTS

**LIST OF FIGURES**

**Page**

## LIST OF TABLES

**Page**

# CHAPTER 1
# INTRODUCTION

The usage of technology and internet by educational institutions has reached the highest level compared to previous periods with the effect of the Covid-19 pandemic. In this process, the concept of distance education has spread rapidly. According to a study by Bouchrika (2021), approximately 4.6 million college students are taking their classes online and about 49% of students have taken at least one form of online course. Thus, Learning Management Systems (LMS), which enable the systematic monitoring and reporting of educational activities, gained even more importance. In fact, in this period of rapid progress towards digitalization, it can be said that LMS have almost taken the place of face-to-face educational activities. Even in the early 2000s, according to Aybay & Dağ (2002), a LMS was inevitable to increase the interaction between the instructors and the students, and therefore Eastern Mediterranean University established its own LMS.

Figure 1.1 is the global monitoring of school closures caused by Covid-19. According to the UNESCO (2020) April 12, 2020 report, a total of 1,576,021,818 students, 90.1% of the students enrolled in education in 192 countries, were affected by the closure of schools due to the Covid-19 outbreak. With this sudden interruption in face-to-face education experienced on a global scale, educational organizations that already have an e-learning tool such as LMS, have started to provide their interrupted education through LMS, a distance education model. Institutions that do not have any LMS yet, have attempted to adapt the LMS that best suits their systems and needs as quickly as possible in order to ensure the educational sustainability.

According to some research results, educational activities stopped during the Covid-19 period due to lack of resources in some universities (e.g. Viner et al., 2020). Even if the resources are sufficient, distance education has been interrupted in many faculties using LMS, due to technical problems and the inability to apply LMS properly (Boram, 2020). It can be said that with the Covid-19 pandemic, the increasing importance of LMS has become more visible.

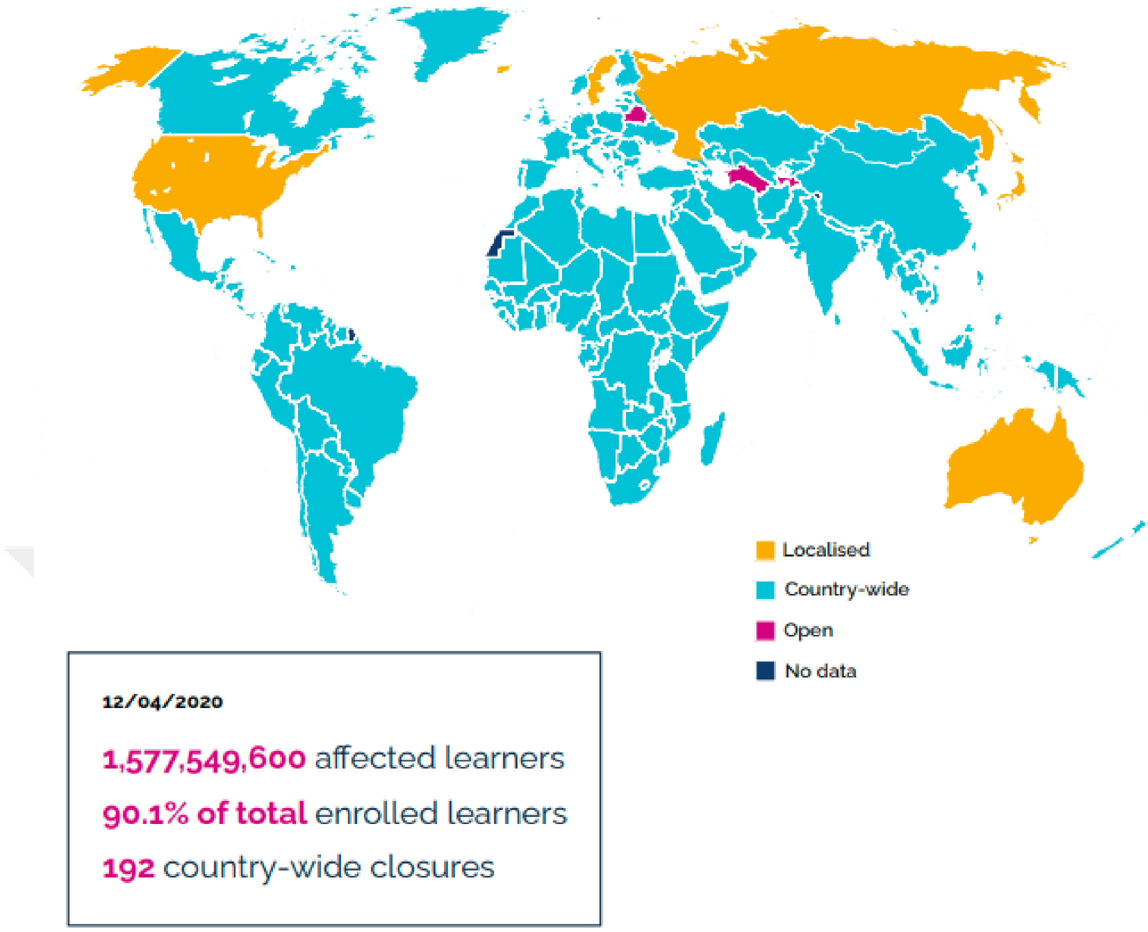


Figure 1.1 Global monitoring of school closures caused by Covid-19 UNESCO (2020)

LMSs ensure the sustainability of the interaction between lecturers and students without time or space limits. According to the research of Bouhnik & Marcus (2006), it is found that the satisfaction of the students with the e-learning course depends on the interaction factor. In other words, in cases where the interaction dimension is unsuccessful, student satisfaction will be negative. Although distance education is widely practiced out of necessity during the Covid-19 pandemic, many studies, including the study by Al-Sofi (2021), have shown that students are satisfied with the usage of LMS. Thus, although the effects of the pandemic have passed and face-to-face education has returned, many educational institutions still continue their educational activities through LMSs. According to the research conducted by Bougrika (2021), 90% of students prefer learning online to traditional learning methods. In line with this, the study of Alturki & Aldraiweesh (2021) showed that

LMS increased the sustainability of students towards educational content during the Covid-19 pandemic. The earlier claim of Epping (2010) that LMS maintain higher quality academic activities in overcapacity classroom conditions, also supports these studies.

Although LMSs was primarily used as a platform for resource sharing or announcements before Covid-19, its purpose of use has expanded further after Covid-19. An average LMS used in any educational institution includes the system in which live lessons are conducted. It ensures resource sharing, announcements, and continuity of classroom communication. Project submissions and online exams can also be conducted via LMSs. As Martin et al. (2008), LMS is a key enabler of lifelong learning for educational institutions since it removes time and space barriers. According to Cigdem & Ozturk (2016), the primary purpose of using LMS is to offer new learning and teaching methods that meet various educational needs.

It is possible to say that LMS have both advantages and disadvantages in both directions. Many opportunities of face-to-face education are carried out on the online platform in order not to be disrupted through LMS. At this point, it is a requirement to follow up whether the education takes place without interruption. Regarding to Meiselwitz & Sadera (2008), students' learning outcomes are dependent to online learning system's usability. Therefore, usability of the system is one of the most important indicators to measure the system's quality.

As International Organization for Standardization (2018), usability is "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of user.". Shackel (1991) defined usability as the ability of people to use the system easily and effectively. Nielsen (2012) defined usability as a quality attribute that assesses how easy user interfaces are to use. It is stated to evaluate usability there need to be 5 components which are learnability, efficiency, memorability, errors and satisfaction again by Nielson (1993). It should also be noted that the usability evaluation factors put forward by Nielsen are the most widely accepted factors in this context.

Various LMS are used by various educational institutions. Institutions continue their distance education activities with the appropriate LMS depending on the education provided within the institution and the expectations of the users. As Thuseethan et al. (2015), majority of educational institutions particularly prefer to use open source and easy-to-customize LMS. SAKAI is one of these LMS and is used by many educational institutions. SAKAI is an open source system with flexible structure. It is shaped by the developers according to the wishes, needs and requirements of the institution that will use SAKAI.

Within the scope of this study, the perceived usability evaluation of the SAKAI platform, which is used in practice by an educational organisation is made. A comprehensive MCDM approach for perceived usability evaluation of LMS is developed. Axiomatic Design Procedure (ADP) is considered as an appropriate MCDM method for perceived usability evaluation of LMS, as the dimension of satisfaction can best be measured with ADP. It also allows an easy approach for data fusion and setting performance targets for decision makers.

In order to evaluate of a system's usability, the system is examined from many different dimensions. In the literature, many factors have been defined in this analysis, depending on the structures of the evaluated system. Among these factors in the literature, Nielsen's (1993) 5 quality factors of usability and Seffah et al.'s (2006) usability criteria are selected and an integrated model of both studies is created for the perceived usability evaluation of the SAKAI system. Within this integrated model, a detailed questionnaire using a 5-point Likert scale is prepared and directed via an online platform to the faculty members, graduate students and undergraduate students of the educational organization. Data collected from users about usability criteria and their importance with the questionnaire is analyzed statistically. The Analytic Hierarchy Process (AHP) and between-group statistical significance tests are applied. Finally, ADP is performed to evaluate perceived usability of the SAKAI-LMS that is in use at the university.

In the structure of the study; chapter two includes both the studies about the perceived usability evaluation of LMS and studies about ADP in the literature. In chapter three, the basis and purpose of this study and usability criteria used are explained. In chapter four, the content of the questionnaire applied in the study is explained. The outputs of the questionnaire are analyzed through statistical tests and criterion weights are found by the AHP method. Afterwards, the application of the ADP to the analyzed data and the findings of this application are presented. Conclusions are given in the chapter five.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Software Usability

As technology developed, software began to appear in all areas of our lives and many new markets emerged in this field. As the use and diversity of software increases, the quality of the software has become more important. Software quality has many attributes. Software usability is one of the most important software quality attributes, and it is also one of the most important indicators of the success of the system. The concept of Usability Engineering (UE) is defined by Nielson (1993) as “the systematic approach to improving the usability of user interfaces by applying a set of proven methods throughout the system development lifecycle”. The software development life cycle generally has the following elements:

- Defining targets, taking into account the future needs of the system,
- Designing the system plan,
- The code of the system is written within the framework of the planned design,
- The system is tested to detect and fix bugs before they are given to the end user,
- The system is delivered to the end user,
- Providing bugfixes and continuous improvements with end user feedback.

Figure 2.1 demonstrates the software development life cycle. There are lots of software usability evaluation methods in the literature. It is important that suitable evaluation method selection for the system structure and at what stage of the software development life cycle the usability assessment should be applied. While software developers generally make the usability evaluations during the software development life cycle process, a usability evaluation is made on the currently used software system in this study.

Blecken et al. (2010), stated that ergonomics should also be taken into account in the usability assessment process and this should be applied in the development phase of the software development life cycle. Sagar & Saha (2017), systematically reviewed usability-related studies from 1990 to 2016. In their review, they found that in software development life cycle, usability related problems occurred in the design phase in 71% of the studies. The result of this study sheds light on which stage of the software development life cycle the usability assessment should be applied. In fact, although usability evaluation is important in each phase, the end-user feedback received during the deployment process is generally more realistic and guiding.

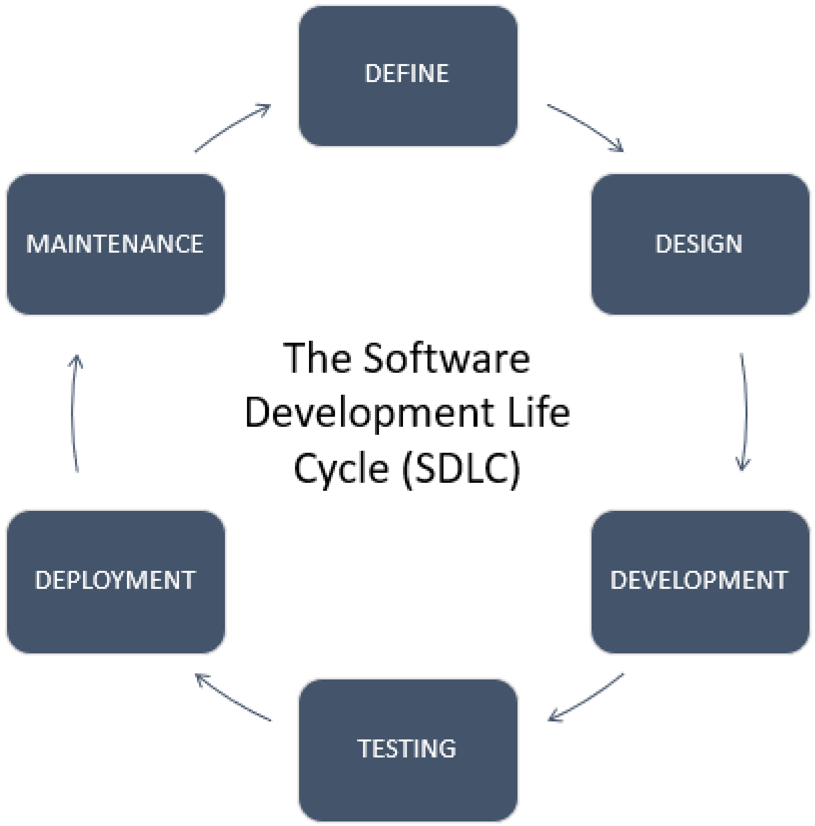


Figure 2.1 The Software Development Life Cycle (SDLC)

## 2.2 LMS Usability Evaluation Methods

Software appears in many aspects of life. The ability of people to adapt to software system depends on the perceived usability of the system. The focus of this study is a case study on the perceived usability evaluation of LMSs. Companies that want to train their employees, many educational organizations, high schools, universities and many organizations benefit from LMS. As mentioned before, especially after Covid-19, many schools stopped their face-to-face trainings and increased the use of LMS and adopted the concept of distance education. People to find LMS easy to use, the ability to adapt to LMS and satisfied with the system, depends on the perceived usability of the system. This will also increase the efficiency in the educational outputs of the system users (e.g. students, faculty members, etc.). According to Zaharias & Poulymenakou (2009), the design and usability of LMSs have the greatest impact on the user's sustainability of the e-learning process.

With the evolution of education in this direction, many studies are carried out on the usability evaluation of LMSs. The metrics on which these evaluations will be made and which techniques will be used are the critical points. There are many studies in the literature for the perceived usability evaluation of LMSs. Various methods have been developed for various objectives such as choosing the appropriate LMS for the organization, evaluating the usability of the currently used LMS or comparing it with other LMSs.

Figure 2.2 demonstrates the frequently used methods in usability evaluations in the literature. Among the methods shown here, it is seen in the literature that heuristic evaluation, and usability testing methods, especially the questionnaire method, have been used in many studies.

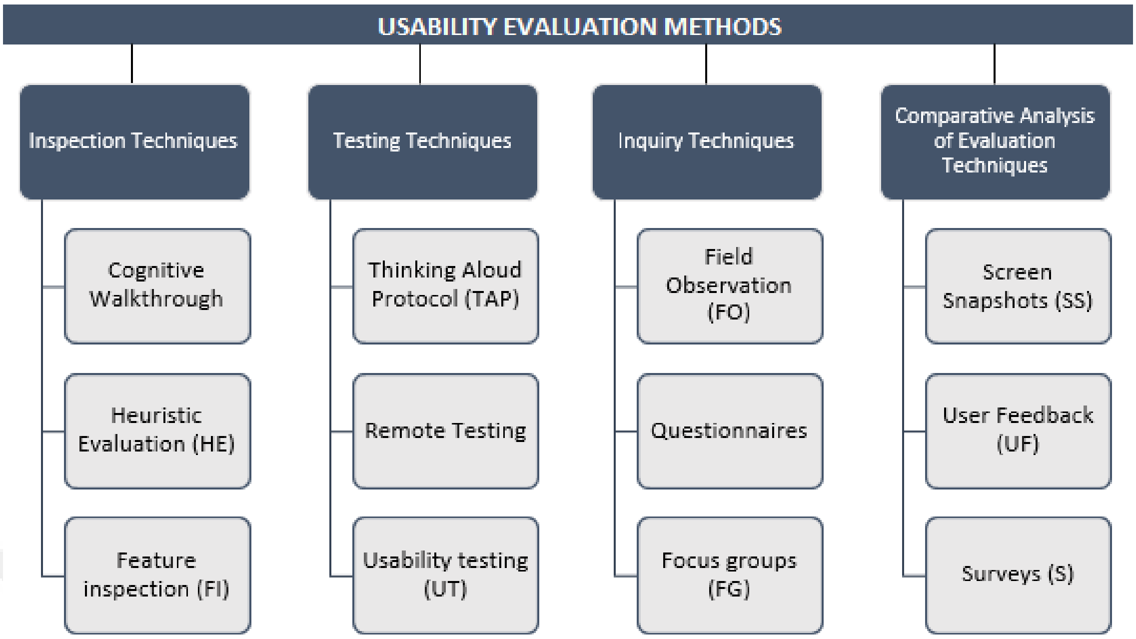


Figure 2.2 Frequently Used Methods in Usability Evaluations in the Literature

In software usability evaluation, questionnaires can evaluate the perceived dimension in the best way and collect the largest amount of data in the most systematic way. It allows to measure users' perceptions of the system within the framework of certain quantitative values. It enables data collection and compilation processes to be done quickly (Gupta & Khanna, 2017). There are standardized questionnaires in the literature. Some of them are listed below:

- SUMI (Software Usability Measurement Inventory, Kirakowski et al. 1986),
- WAMMI (Website Analysis and Measurement Inventory, Kirakowski et al. 1996),
- QUIS (Questionnaire for User Interaction Satisfaction, Chin et al. 1988),
- TAM (Technology Acceptance Model, Davis, 1989),
- SUS (System Usability Scale, Brooke, 1986).

The first version of SUMI was created in 1986 by Krakowski et al. It is a 50-item fixed questionnaire with subsections where efficiency, affect, helpfulness, control and learnability elements are evaluated separately. It has questions that do not have details and also have outdated validity. Although allowing only objective evaluation is appropriate for evaluating the perceived dimension of usability, it is a disadvantage that cannot be ignored that evaluation of many aspects of the software is out of focus. In addition, large sample sizes are not suitable for evaluating many aspects of the software. Due to these features and its inflexible structure, the disadvantages outweigh the advantages of questionnaire applicability.

WAMMI is a 20-item questionnaire created by Krakowski et al. in 1996. It is a 5-point Likert scale with subsections as attractiveness, controllability, efficiency, helpfulness, and learnability. It has the same objective structure as SUMI and is a scale suitable for use in the measurement of perceived usability. It is low cost and enables comparisons of WAMMI-measured websites with each other. It has inflexible questions like SUMI and can only be used until the development process.

QUIS was developed by Chin et al. in 1988. They also proved the reliability and validity of the method. It is a method that can be applied before and after development and is also cost efficient. It is evaluated with 6 subscales on 9-point scale. There are 11 interface factors in the questionnaire, and it measures the user's overall satisfaction with the system's interface through these factors.

TAM is a 20-item standardized questionnaire developed by Davis et al. in 1989. Figure 2.3 demonstrates the technology acceptance model. It both measures and aims to increase the acceptability of the system by the user. It provides the acceptability of the system and the intention to use by users within the framework of perceived usefulness and perceived ease of use factors. It has a flexible structure that allows questions to be created in accordance with the system. It is a fast and practical usability evaluation method that can be applied before and after the development process. Unlike SUMI and WAMMI, it has a subjective structure. Although there are studies that analyze and support the validity and reliability of TAM and show its contribution to user intention to use (e.g. Wu et al., 2007; Mathieson, 1991; Segars & Grover, 1993; Doll et al., 1998), it has been argued by some studies (e.g. Kim et al., 2009; Agarwal

& Prasad, 1999) that user attitude should be included in this model. The method has the disadvantage that there are contradictions in the literature regarding its validity.

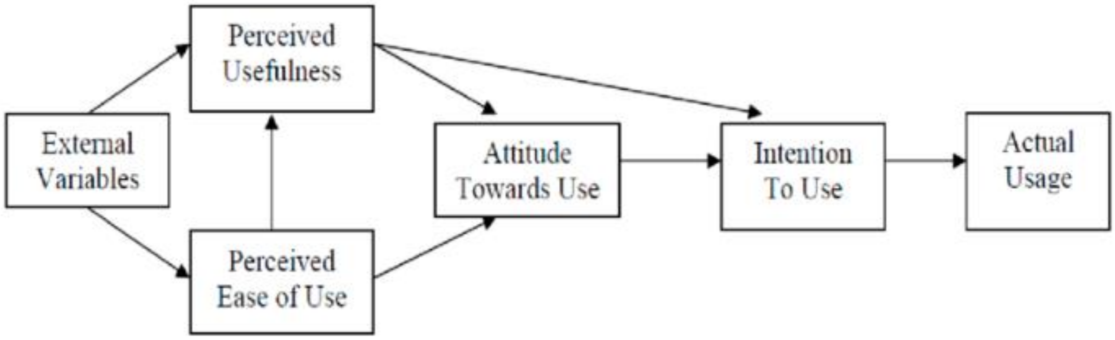


Figure 2.3 Technology Acceptance Model (TAM) Adopted from Davis et al. (1989)

SUS, which enables to use user feedbacks for perceived usability evaluation, is the most commonly used standardized questionnaire in the literature (Lewis, 2018a; Sauro & Lewis, 2009). It has been translated into many languages and its applicability has been made universal. According to Sauro's (2011) work, it has a flexible structure that it can be used in the perceived usability evaluation of many diverse systems, technologies and products. It has 10 items and uses a 5-point scale. In tests performed on the scale, reliability, validity and sensitivity values were found to be very high (Sauro & Lewis, 2016). It is both cost efficient and a shorter scale compared to other scales. In various studies, it has been observed that SUS can distinguish the usability of systems better than SUMI, WAMMI and QUIS (e.g. Tullis & Stetson, 2004; Sauro, 2011).

## 2.3 LMS Usability Evaluation in the Literature

In the literature, it has been seen that SUS and TAM scales are widely used in LMS usability evaluations. SUS has been the preferred method in the perceived usability evaluation in this study, due to its high validity and acceptance, and its flexible structure.

The current study is inspired by the study of Önaçan & Ertürk (2017) in terms of determining the features that need to be developed. They emphasized the importance of LMS in terms of effectiveness and efficiency in their studies. They developed a new questionnaire, which they called the Scale for Usability of Learning Management System (SULMS), to evaluate the usability of an LMS that has been in use for 2 years in an institution. While developing this scale, in which they evaluated 5 usability factors defined by Nielsen (2012), they benefited from several scales, especially the System Usability Scale (SUS), which was introduced by Brooke (1986). They purified their items and calculated the reliability and the content validity of them. As a result, they developed a new scale that can be used and developed to measure usability and user satisfaction in other systems.

Seffah, Donyaee, Kline & Padda (2006), examined the shortcomings and non-complementary aspects of models based on usability as a quality factor. They have developed a new model called Quality in Use Integrated Measurement (QUIM) by revealing that the existing models are not created within a certain scope in the same direction with each other. Within the scope of this model, 10 complementary factors of usability, 25 subfactors of these factors and then evaluating them within 127 specific metrics were put forward. Through QUIM, they aimed to address the usability concept in all its aspects and to integrate it with software applications. They made the definitions of all the factors and criteria they compiled, showed the relationship between these factors and criteria, and then calculated their metrics. This study has shed light on this thesis especially in defining usability evaluation criteria, as it will be discussed in more detail in the following chapters.

Senol et al. (2014), evaluated the usability of the MOODLE as a LMS, which is used by Kocaeli University. They applied a questionnaire to the students in order to evaluate the usability of the system. As in this study, they also benefited from Nielsen's (1993) 5 usability factors, which are learnability, efficiency, memorability, errors and satisfaction. According to the results they obtained from the questionnaire, they concluded that making the interface of the MOODLE system more aesthetic and increasing the usage tips for the users would increase the usability of the system. As a result, it can be said that they carried out a simple study with a questionnaire application without resorting to complex methods.

Pal & Vanijja (2020) conducted a perceived usability evaluation of the Microsoft Teams online learning platform. In order to make this evaluation, they used both SUS and the Technology Acceptance Model (TAM). Users were presented with a questionnaire containing both approaches. According to the questionnaire results, they determined that the SUS and TAM models can be used in the evaluation of perceived usability. After statistical analysis, it was found that SUS and TAM models gave identical results and Microsoft Teams application is usable.

Hirval & Zaim (2021) performed the usability evaluation of SMKN 2 Padang LMS, which is used in English education. In order to make this evaluation, they directed the USE Questionnaire with a Likert scale to students and teachers. The USE Questionnaire was created by Lund (2001) for the purpose of measuring usability. It consists of 4 categories (namely usefulness, ease of use, ease of learning and satisfaction) and 30 statements related to these categories. As a result of the study, the usability of the relevant LMS was found to be satisfying.

Kakasevski et al. (2008), also carried out the usability evaluation of MOODLE system, but in a slightly different way. They evaluated the system by its modules before they implement it. The students were directed to complete 3 types of questionnaires and tasks to complete. In their third questionnaire, they used 5 usability dimensions as ease of use, efficiency, effectiveness, memorability, satisfaction and they matched each single question with them. They statistically analyzed the gathered data. In line with the results they obtained, they implemented the MOODLE system that would be most suitable for the users.

Thuseethan et al. (2015) evaluated the usability of MOODLE LMS used in Sri Lankan universities on the basis of 2 approaches. In order to evaluate the usability criteria they determined, they used an approach similar to that used in this study. They created 2 questionnaires taking into account the Likert Scale and directed them to more than 200 participants from 7 universities. In another approach, they tested the effectiveness of the relevant LMS system with the tasks they directed to the participants. As a result of the study, they determined that the students were generally satisfied with the current system, even if the system had some shortcomings in terms of usability.

Dubey et al. (2012a) have defined the concept of software usability. They also used an integrated model for software usability evaluation. They defined effectiveness, efficiency, satisfaction, comprehensibility and safety as their attributes and their sub-attributes. Unlike other studies in the literature, they analyzed the concept of software usability and its attributes in more detail and compared them with other studies in the literature.

In the literature, it is seen that Nielson's (1993) 5 usability factors are widely used in studies on LMS usability evaluations. According to the results of systematic literature review by Sagar & Saha (2017), it is seen that efficiency, effectiveness, satisfaction, and learnability factors, most of which are Nielson's usability factors, are the most used attributes in software usability evaluations. Table 2.1 shows some studies using some of Nielson's (1993) 5 usability factors. These studies are effective in the selection of the 5 usability factors used in the perceived usability evaluation in this study. The usability factors, designed questionnaires and approaches used in these studies are also effective in the formation of the methodological approach in this study.

Table 2.1 Some studies using some of Nielson's (1993) 5 usability factors

| | Learnability | Efficiency | Memorability | Errors | Satisfaction |
|---|---|---|---|---|---|
| Önaçan & Ertürk (2017) | X | X | X | X | X |
| Seffah et. al (2006) | X | X | | | X |
| Senol et. al (2014) | X | X | X | X | X |
| Hirval & Zaim (2021) | | | | | X |
| Kakasevski et. al (2008) | | X | X | | X |
| Thuseethan et. al (2015) | X | | | | X |
| Dubey et. al (2012a) | | X | | | X |
| Harrison et al. (2013) | X | X | X | X | X |
| Abran et al. (2003) | X | X | | | X |
| Alonso-Rios et al. (2009) | | X | | | X |
| Donyaee et al. (2001) | X | X | | | X |
| Quesenbery (2004) | X | X | | | |
| Frokjaer et al. (2000) | | X | | | X |
| Constantine et al. (1999) | X | X | X | | X |
| Battleson et al. (2001) | X | | X | X | |
| Shackel (1991) | X | | | | |
| Brinck et al. (2002) | X | X | X | X | |

Dubey et al. (2012b), proposed a fuzzy multi-criteria weighted average approach in order to evaluate of a software usability. They determined effectiveness, efficiency, satisfaction, comprehensibility and safety as their usability factors. By defining sub-attributes with sub-characters to these factors, they created a criteria tree and an integrated model. Each sub-attribute is considered a level and is fuzzy weighted. As a result, fuzzy multi-criteria weighted average method has been proposed for the usability evaluation of multi-criteria software systems.

In this study; MCDM methods are used in order to make the necessary decision for a system whose criteria are determined. System data are collected through a questionnaire in the SUS framework. The data of the relevant system are collected by scaling the verbal evaluation criteria numerically. The data is made meaningful with some statistical processes. Afterwards, AHP is used to determine the criterion weights and ADP is used to evaluate the perceived usability evaluation of the system. Therefore, among the MCDMs, the ADP is chosen to be used in the perceived usability evaluation of the relevant system.

ADP is used in the design process of the Product/Software development life cycle to design a quality product. With its axioms, ADP helps the decision maker in the decision making process by finding the best among various system design alternatives. Thus, repetitive trials are minimized and the system becomes cost and time efficient. Determining performance targets, simplifying the problem and having a more systematic solution approach are the advantages that facilitate the decision-making process.

ADP has a structure that can examine both quantitative and qualitative data. Thus, it is a more suitable method for the evaluation of perceived usability compared to other multi criteria decision making methods. When the literature is reviewed, it is seen that the ADP method is used in usability evaluations and software design phases (Arsenyan, 2014; Guo, 2014) but it is not used in any LMS usability evaluation. With this thesis, it is aimed to develop a systematic new method in which the ADP method is used in LMS perceived usability evaluations.

In the literature, the ADP is encountered in many different applications. Pimentel & Stadzisz (2006) developed a method in order to achieve a higher quality software design by adopting the object-oriented software design approach of the software in the design process. They proposed a model that integrates the Axiomatic Design, the Unified Modeling Language, and the Unified Software Development Process. As a result of their studies, they have reached a quality system design with the Axiomatic Design method integrated into the design concepts.

Arsenyan & Büyüközkan (2014) developed a collaborative product development (CPD) model by utilizing ADP that can be used in collaborative projects. They verified the model they developed with their analysis and examined the model performance with a case study. As a result, they developed an AD-based software development method that makes the system more efficient and evaluates the system performance collaboratively.

Güngör (2017) carried out a study on the selection of seal material for a machine manufacturer with the Axiomatic Design method. Fuzzy numbers and criterion weights were not used in the study. As a result of the study, PP-PolyPropilen material with the smallest information content value was selected among the alternative materials in line with the criteria.

Çelik et al. (2020), applied the ADP in the selection of bead Polystyrene Rigid Foam (EPS). In the first stage of their work, they accepted the weight of each criterion as equal and changed the design intervals to find and compare the information content values in different cases. In the second phase of their work, they found the weight of each criterion with the Analytic Hierarchy Process (AHP) and found the information content values by including the weights of these criteria. When all the cases were compared, it was decided that Alternative 2 was the most suitable option.

Subulan & Baykasoğlu (2021), worked on a route selection real-life problem and they proposed a Weighted Hierarchical Fuzzy Axiomatic Design method. They collected both fuzzy and crisp data via questionnaire and applied both weighted and unweighted Axiomatic Design method. As a result, decision makers on the basis of the study decided that the Weighted Fuzzy Axiomatic Design method is the most usable method in their route selection problem.

Karataş & Akman (2009), conducted a study on the evaluation of innovative cultural structures of machinery manufacturers. They determined 8 criteria on the basis of the relevant factor belonging to the companies and prepared a questionnaire on the basis of these criteria. The questionnaire applied to 16 companies. Within the questionnaire, it was presented on a scale that provides 1-9 pairwise comparisons of the determined criteria and the AHP method was applied to the results of the relevant scale. In this way, the priorities of the criteria were also calculated. They analyzed the results of the survey with the Axiomatic Design method, which makes it possible to evaluate both quantitative and qualitative criteria. The AD method was applied both with and without weights and the results were compared to determine which companies had more innovative culture. In this study, an LMS usability evaluation will be presented by using the general structure of the study by Karataş & Akman (2009).

# CHAPTER 3
# PROBLEM DEFINITION AND METHODOLOGY

## 3.1 Problem Definition

As discussed in the previous chapter, software usability has been evaluated in many studies by various criteria. Various evaluation frameworks were created by using a set of software usability evaluation criteria suitable for the structure of the problem in each of them. Many of these previous studies are reviewed and an integrated model of the QUIM model created by Seffah et al. (2006) with the 5 usability factors defined by Nielsen (1993) is created. 25 usability criteria of Seffah et al. (2006) is combined under the 5 usability factors of Nielsen (1993) according to their suitability for the current system. With these developed criteria and their sub-criteria model, the perceived usability evaluation of SAKAI-LMS that is in use at an institution, is made.

SAKAI is a free and widely used, open source LMS, generally customized for higher education institutions. It includes many tools such as Announcements, Resources, Assignments, Tests & Quizzes and has a structure that is open to use by being customized for the institution. Due to the multifaceted nature of LMSs, usability evaluations should also be examined in a multifaceted manner and in accordance with the structure of the system.

### *3.1.1 Factors and Criteria*

The first step of this study, which is created to evaluate the SAKAI-LMS's usability, was to determine the criteria. Accordingly, 25 usability criteria of Seffah et al. (2006) were integrated under the 5 main usability factors of Nielson (1993). These 5 main usability factors, which are Learnability, Efficiency, Memorability, Errors, Satisfaction and the criteria grouped under them are shown in Figure 3.1.

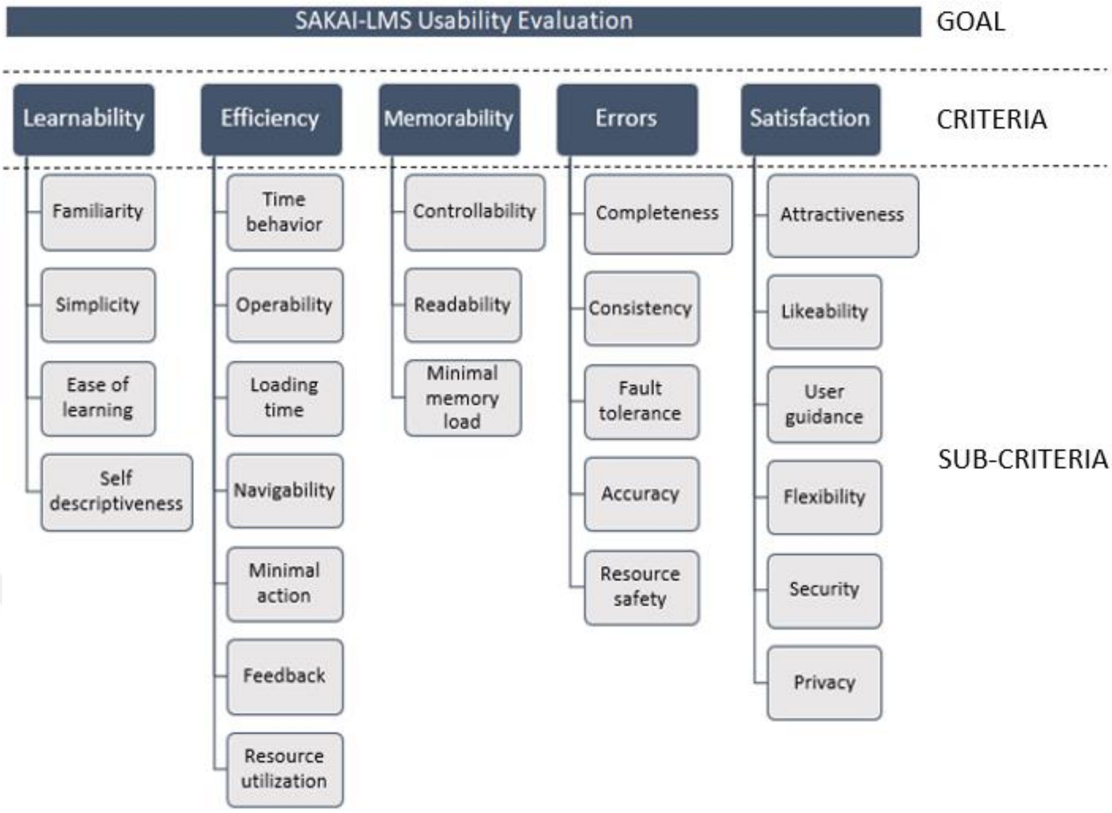


Figure 3.1 Proposed criteria framework for SAKAI-LMS usability evaluation

Many criteria have been used in various variations in the literature. These options can be increased or decreased in line with the purpose of the study and the structure of the system. In this study, 5 main usability factors of Nielson (1993) and 25 usability criteria of Seffah et al. (2006) is chosen, since the aim is to evaluate the selected system in detail from many aspects. These factors and criteria can also be used in usability evaluations of other software systems. Since the purpose here is to evaluate the perceived usability of an LMS, which is SAKAI platform in this case, the determined criteria were used accordingly. Factors and criteria can be considered as the building blocks of this study. Therefore, the meaning of each factor and criterion should be well understood. The explanations of each criterion and the usability factor it depends on are given in the Table 3.1 Many of them are explained in Seffah et al. (2006) and are used with similar directions in this study.

Table 3.1 Definition of the factors and criterion

| Criteria | Definition |
| --- | --- |
| **Learnability** | Learnability is the quick and easy learning of existing and new features of the relevant software by users (Seffah et al., 2006). |
| Familiarity | It is the expression of the user interface created with understandable elements (Seffah et al., 2006). |
| Simplicity | It is the absence of non-functional foreign elements in the user interface (Seffah et al., 2006). |
| Ease of learning | It is the ease of learning of the software by the users. |
| Self-descriptiveness | It is the understandable user assistance provided by the software to the user in user operations (Seffah et al., 2006). |
| **Efficiency** | It is expressed by the appropriate amount of resource expenditure in the use of the product by the users (Seffah et al., 2006). |
| Time behavior | It is the ability to perform operations on the software at appropriate times (Seffah et al., 2006). |
| Operability | The effort required by the user to run and use the software (Seffah et al., 2006). |
| Loading time | Responsiveness of the software web page when loading (Seffah et al., 2006). |
| Navigability | Indicates that users cannot easily navigate through the user interface (Seffah et al., 2006). |
| Minimal action | The number of steps required for users to perform the operations they want to perform (Seffah et al., 2006). |
| Feedback | It is the ability of the software to provide meaningful responses and returns to the actions performed by the user (Seffah et al., 2006). |
| Resource utilization | Capability to consume appropriate amounts and types of resources when the software performs its function (International Organization for Standardization, 2011). |
| **Memorability** | It is the retention of the software by the user so that it can perform the necessary operations (Seffah et al., 2006). |
| Controllability | It is expressed by users feeling the control of the software while using the software (Seffah et al., 2006). |
| Readability | Visual readability of texts in the user interface by users (Seffah et al., 2006). |
| Minimal memory load | The multiplicity of operations that the user must keep in his memory in the operations to be performed in the use of the software or the memorability of the operations to be performed by the user in the time between uses (Seffah et al., 2006). |

Table 3.1 Continues

| | |
|---|---|
| **Errors** | Errors that the software may have on both the back and front. |
| Completeness | It is the completeness of the operations in the software (Seffah et al., 2006). |
| Consistency | Whether the items in the user interface are in the same format (Seffah et al., 2006). |
| Fault tolerance | Capability of the software product to maintain a specified level of performance in cases of software faults or of infringement of its specified interface (International Organization for Standardization, 2011). |
| Accuracy | Capability to provide correct results or effects (International Organization for Standardization, 2011). |
| Resource safety | It is the safe processing of resources (Seffah et al., 2006). |
| **Satisfaction** | Satisfaction refers to users' personal feelings about whether they are satisfied with the use of the software (Seffah et al., 2006). |
| Attractiveness | Capability of the software product to be attractive to the user (e.g., through use of color or graphic design), (International Organization for Standardization, 2011). |
| Likeability | User’s perceptions, feelings, and opinions of the product (Rubin, 1994). |
| User guidance | It is whether understandable and clear guiding warnings occur in the user interface (Seffah et al., 2006). |
| Flexibility | Indicates whether the user interface can be personalized or not (Seffah et al., 2006). |
| Privacy | It is the protection that the software provides for user personal information (Seffah et al., 2006). |
| Security | Capability of the software product to protect information and data so that unauthorized persons or systems cannot read or modify them and authorized persons or systems are not denied access (International Organization for Standardization, 2017). |

## 3.2 Methodology

The planning of the study is designed before realizing the study and the relevant plan is followed through. Many studies on LMS usability evaluation and MCDM use in the literature are searched and analyzed. The place of distance learning concept and LMSs in the literature are investigated and analyzed as the first stage of the study. A comprehensive literature review is conducted on the usability evaluation of LMS. As a result of these reviews: A comprehensive MCDM model, which has no previous example in the literature, is developed and percevied usability evaluation of an LMS is performed as a real life case study.

After literature review, problem definition is made. The model developed in this study for the perceived usability evaluation of the SAKAI-LMS, integrating 2 sets of criteria previously defined in the literature, is described. Definitions of each main criteria and sub-criteria is made. In the following, the methodological framework is explained in this chapter.

In the defined methodoligal framework, studies on data modeling and data analysis is carried out. During the modeling phase, a questionnaire is designed to perform the perceived usability evaluation for the currently used SAKAI-LMS and applied to actual system users namely, undergraduate students, graduate students and faculty members. The questionnaire is created to cover each main criteria and sub-criteria. After the data collection through the questionnaire, as the first step of the data analysis, statistical analyzes of the data collected from the system users is made. Statistical analyzes covers the knowledge level, perceived importance and perceived fulfillment levels of the system users. Each analysis is made separately for each evaluation group.

Afterwards, significance tests are performed using the Statistical Package for the Social Sciences for the values obtained from the statistical analyzes. Significance test is performed to determine whether the data obtained from the evaluation groups has significant differences. In the later parts of data analysis, MCDM methods are used. The AHP and point allocation procedures are utilized to determine weights for main-criteria and sub-criteria. Since there is significant differences between the evaluation groups according to the Significance test results, a separate AHP method is applied for each evaluation group.

In the last stage of data analysis, the perceived usability evaluation of the SAKAI system is carried out using ADP, using all the data collected so far.

Finally, discussion and conclusions are made about the research. The contribution of the findings to the literature and the aspects that differ from other studies in LMS perceived usability evaluations are mentioned. Figure 3.2 demonstrates the mentioned methodology of the study.

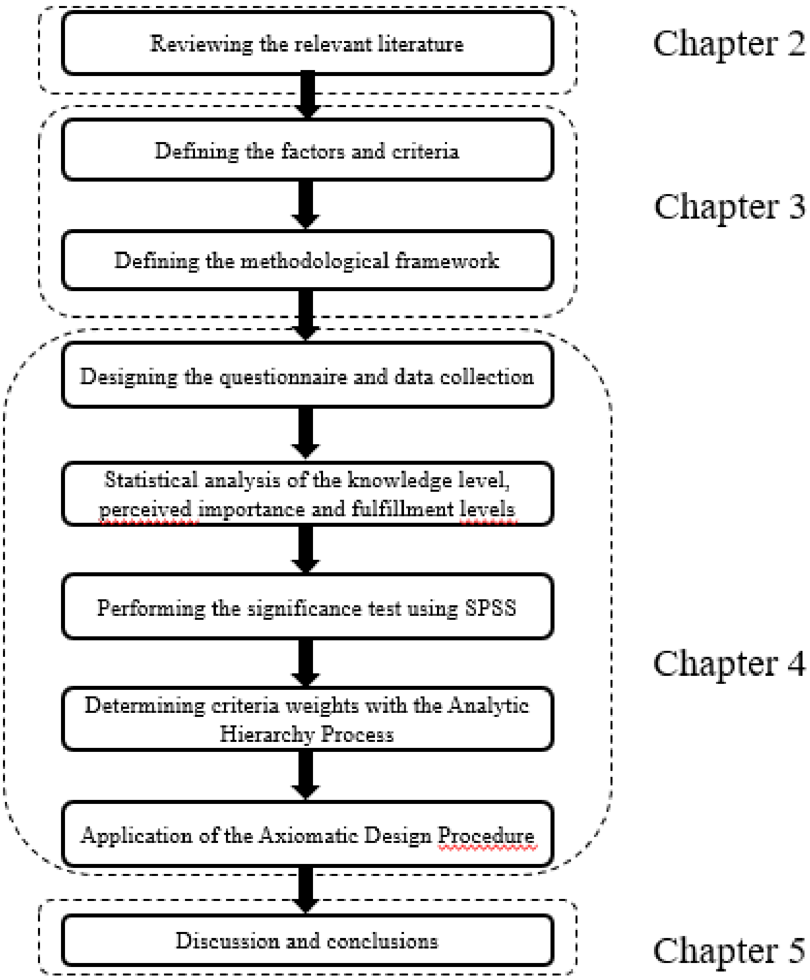


Figure 3.2 Structure of the study

# CHAPTER 4
# MODELLING AND DATA ANALYSIS

## 4.1 Data Collection

### *4.1.1 Structure of the Questionnaire*

After determining the factors and criteria, the next step is to evaluate the perceived usability of the SAKAI-LMS over the criteria. In order to evaluate of a systems usability, the System Usability Scale (SUS) which is found by Brooke (1996), is the most widely used scale. SUS which is also a 5-point Likert scale, asks respondents to evaluate the questions asked with a 5-point scale. In this study, a questionnaire is prepared based on the SUS.

Questionnaire basically consists of 4 parts. First of these is the general information section which includes 3 questions. At the beginning of the questionnaire, the participants are asked whether they participated in the survey voluntarily or not. Thus, the questionnaire is presented to the participants who only voluntarily agreed to participate in the questionnaire. Respondents who agreed to participate in the questionnaire are asked whether they are faculty members, graduate students or undergraduate students. Then, the respondents are asked what level of knowledge they have about LMSs in the range of 1-5, with a minimum of 1 and a maximum of 5.

The second part includes questions related to perceived importance level for each usability sub-criteria. In the third part, there are pairwise comparisons of the main usability criteria perceived importance levels in terms of usability. Saaty's (1980) from 1 to 9 scale is used. 1 being equally important and 9 being extremely important. Respondent is asked to mark the scale close to the factor that the respondent thinks is more important in terms of usability. Finally, in the fourth part, perceived fulfillment level of each usability sub-criteria for SAKAI- LMS are evaluated.

In the second and fourth sections, where the perceived importance and fulfillment of the usability criterion are evaluated, each question corresponds to a sub-criteria and is evaluated in the range from 1 to 5. For both the second and fourth sections, 1 represents the lowest and 5 represents the highest. During the creation of the questionnaire, special attention is paid to make it understandable by the respondents both on the basis of questions and in terms of the ordering of the sections. In line with this purpose, the final version of the questionnaire is reached with some user tests at the stage of creating the questionnaire.

Except for the first part of the questionnaire, where information about the respondent is collected, other parts are given in the appendices. Appendix A gives second part of the questionnaire, where the perceived importance level for each usability sub-criteria is evaluated. In Appendix B, the third part, pairwise comparisons of the main usability criteria perceived importance levels are evaluated, while in the Appendix C, the fourth part, perceived fulfillment level of each usability sub-criteria of the SAKAI-LMS is evaluated. As mentioned, each question is created based on a sub-criteria. The criteria on which the questions are formed are also given in the relevant tables.

### *4.1.2 Questionnaire Sample Size*

The questionnaire is created on an online platform and delivered via online platforms to institution's faculty members, graduate students and undergraduate students. No personal data is collected in the questionnaire, the participants participated in the questionnaire anonymously. The institution has 25 faculty members, 90 graduate students and 700 undergraduate students. 95% confidence level and 5% margin of error is considered and the observed populations are considered homogenous, therefore $p$ and $q$ values are set to 0.9 and 0.1. The number of required responses are calculated via Equation 4.1 and shown in Table 4.1.

$N$: $Population\ size$

$n$: $Optimum\ sample\ size\ to\ be\ determined$

$p$: $The\ probability\ related\ to\ incidence\ of\ the\ investigated\ event$

$q$: $(1-p) The\ probability\ of\ not\ seeing\ the\ investigated\ event$

$d$: $Sampling\ error\ accepted\ by\ the\ researcher$

$t$: $Theoretical\ value\ found\ in\ the\ t\ table\ at\ a\ certain\ degree\ of\ freedom\ and\ confidence\ level$

$$n = \frac{N.t^2.p.q}{d^2(N-1)+t^2.p.q} \tag{4.1}$$

For example, for the undergraduate students evaluation group with 700 people, the minimum sample size is calculated as follows to meet the 95% confidence level and 5% margin of error rates:

$$= \frac{700.(1.96)^2.(0.5).(0.5)}{(0.05)(700-1)+(1.96)^2.(0.5).(0.5)}$$

$$= 249$$

After the questionnaire output is removed from the people who do not continue to the institution or who do not fill out the questionnaire completely even though they have participated in the questionnaire; Number of usable responses obtained from faculty members is 17, corresponding to a %8.23 margin of error; graduate students is 56, corresponding to a %5.53 margin of error; undergraduate students is 116, corresponding to a %4.99 margin of error. Error rates realized as from the Equation 4.2. With an error rate of 4.99%, the data collected from undergraduate students were able to provide the planned error rate.

$$Margin\ of\ error = z\frac{\sigma}{\sqrt{n}} \tag{4.2}$$

Table 4.1 Information on the required sample size

| Respondent Groups | Population size | Number of required respondents (*%95 confidence level and %5 margin of error*) |
|---|---|---|
| Faculty members | 25 | 17 |
| Graduate students | 90 | 56 |
| Undergraduate students | 700 | 116 |

## 4.2 Analysis of the Questionnaire Outputs

### *4.2.1 Analysis of the Knowledge, Importance and Fulfillment Levels*

As explained in the previous chapters, the participants are asked to rate their knowledge level about LMSs in the range from 1 to 5, where 1 refers to very low knowledge and 5 refers to very high knowledge. LMS general knowledge level distributions of all respondents and each evaluation groups are given in Figure 4.1. As it can be seen from Figure 4.1, general knowledge levels of more than %90 of participants are above average (summation of ratings from 3 to 5). Very few participants declared that they have very low knowledge about LMS. It is also noteworthy that the percentages of 4 and 5 points given in evaluation groups increases as they progress from undergraduate students to graduate students and from graduate students to faculty members, respectively. Hereby, all faculty members declared that they have above average general knowledge level about LMSs.

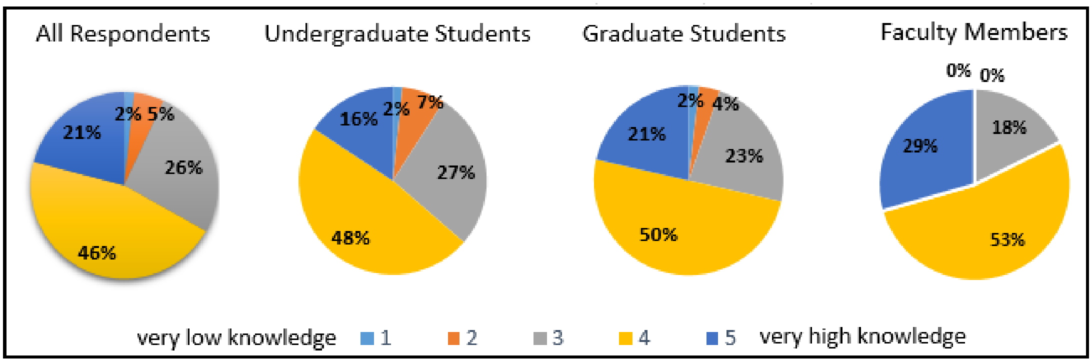


Figure 4.1 Distributions of general LMS knowledge levels

As mentioned earlier, in the second and fourth sections of the questionnaire, perceived importance and perceived fulfillment levels is evaluated. The descriptive statistics of perceived importance and perceived fulfillment values of these collected data for each evaluation group and each sub-criteria are shown in the Table 4.2. Evenly spaced scale is used, with 1 refers to the lowest and 5 refers to the highest. When the mean and standard deviation values of all evaluation groups and all sub-criteria are examined, it is seen that the majority of the mean values are between 3 to 4.

As can be seen from the Table 4.2, faculty members perceived importance average value for the familiarity sub-criteria is 4.12, while the perceived fulfillment average value is 3.65. It can be said that the degree of meeting the familiarity sub-criteria for faculty members by SAKAI-LMS is remained below the criterion perceived importance level. The same inference can be made for the other sub-criteria under learnability criteria for faculty members.

Table 4.2 Descriptive statistics for perceived importance and perceived fulfillment levels of usability sub-criteria by respondent groups

| Criteria | Perceived Importance | | | | | | Perceived Fulfillment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Undergraduate Students | | Graduate Students | | Faculty Members | | Undergraduate Students | | Graduate Students | | Faculty Members | |
| | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. |
| Learnability | | | | | | | | | | | | |
| Familiarity | 3.74 | 1.03 | 4.05 | 0.70 | 4.12 | 1.32 | 3.55 | 1.00 | 3.84 | 0.80 | 3.65 | 0.93 |
| Simplicity | 3.58 | 1.02 | 3.88 | 0.76 | 3.71 | 1.16 | 3.62 | 0.98 | 3.59 | 0.80 | 3.06 | 1.25 |
| Ease of learning | 3.76 | 1.01 | 3.93 | 0.78 | 4.00 | 1.06 | 3.81 | 0.86 | 3.80 | 0.88 | 3.29 | 1.10 |
| Self-descriptiveness | 3.58 | 1.11 | 3.82 | 1.06 | 3.82 | 1.47 | 3.41 | 1.02 | 3.46 | 0.81 | 2.94 | 1.39 |
| Efficiency | | | | | | | | | | | | |
| Time behavior | 3.26 | 1.26 | 4.02 | 0.92 | 4.18 | 1.24 | 3.16 | 1.07 | 3.54 | 0.95 | 3.24 | 0.97 |
| Operability | 3.51 | 1.06 | 3.86 | 0.86 | 3.65 | 1.37 | 3.27 | 0.98 | 3.48 | 0.83 | 3.06 | 1.20 |
| Loading time | 2.92 | 1.44 | 3.64 | 1.14 | 3.88 | 1.45 | 2.81 | 1.19 | 3.41 | 0.89 | 3.00 | 0.87 |
| Navigability | 3.35 | 1.11 | 3.59 | 0.99 | 3.71 | 1.26 | 3.24 | 1.09 | 3.68 | 0.83 | 3.24 | 0.83 |
| Minimal action | 3.31 | 1.23 | 3.48 | 1.04 | 3.59 | 1.42 | 3.16 | 1.06 | 3.34 | 0.92 | 2.65 | 1.00 |
| Feedback | 2.69 | 1.41 | 3.14 | 1.17 | 3.65 | 1.50 | 2.41 | 1.14 | 2.98 | 0.90 | 2.76 | 1.15 |
| Resource utilization | 3.46 | 1.04 | 3.59 | 0.93 | 3.82 | 0.95 | 3.31 | 1.11 | 3.54 | 0.81 | 3.06 | 0.97 |
| Memorability | | | | | | | | | | | | |
| Controllability | 3.72 | 1.13 | 4.02 | 0.73 | 4.00 | 0.94 | 3.48 | 0.97 | 3.55 | 0.85 | 3.18 | 1.01 |
| Readability | 3.65 | 1.02 | 3.84 | 0.85 | 3.76 | 0.90 | 3.51 | 0.90 | 3.59 | 0.87 | 3.12 | 1.05 |
| Minimal memory load | 3.79 | 1.07 | 3.95 | 0.86 | 3.88 | 1.17 | 3.64 | 0.99 | 3.75 | 0.90 | 3.00 | 0.87 |
| Errors | | | | | | | | | | | | |
| Completeness | 2.59 | 1.59 | 3.36 | 1.37 | 3.59 | 1.62 | 1.90 | 0.99 | 2.52 | 1.08 | 2.18 | 1.07 |
| Consistency | 3.15 | 1.33 | 3.57 | 0.97 | 3.94 | 1.30 | 2.64 | 1.02 | 3.39 | 0.85 | 2.71 | 0.99 |
| Fault tolerance | 2.90 | 1.24 | 3.45 | 1.04 | 3.71 | 1.21 | 2.53 | 1.03 | 2.88 | 0.81 | 2.71 | 0.99 |
| Accuracy | 3.08 | 1.25 | 3.48 | 1.06 | 3.82 | 1.24 | 2.60 | 1.05 | 3.23 | 0.85 | 2.94 | 0.83 |
| Resource safety | 3.56 | 1.24 | 3.98 | 0.96 | 3.76 | 1.20 | 3.17 | 1.19 | 3.64 | 0.82 | 3.18 | 0.88 |
| Satisfaction | | | | | | | | | | | | |
| Attractiveness | 2.63 | 1.16 | 3.09 | 1.03 | 3.12 | 1.27 | 2.40 | 1.10 | 2.95 | 1.03 | 2.41 | 1.06 |
| Likeability | 2.23 | 0.99 | 2.80 | 0.92 | 2.76 | 1.15 | 2.29 | 1.12 | 2.80 | 1.00 | 2.29 | 1.05 |
| User guidance | 2.95 | 1.18 | 3.55 | 0.97 | 3.71 | 1.31 | 2.59 | 1.09 | 3.13 | 0.85 | 2.65 | 1.00 |
| Flexibility | 2.59 | 1.12 | 2.95 | 0.96 | 3.71 | 1.10 | 2.40 | 1.04 | 2.79 | 0.99 | 2.59 | 1.12 |
| Privacy | 3.76 | 1.17 | 3.93 | 0.97 | 3.94 | 1.34 | 3.38 | 1.10 | 3.82 | 0.81 | 3.12 | 0.78 |
| Security | 3.74 | 1.11 | 4.13 | 0.95 | 4.18 | 1.01 | 3.35 | 1.07 | 3.96 | 0.81 | 3.18 | 1.07 |

### 4.2.2 Significance Test

In the previous chapter, the mean and standard deviation values of each evaluation group for both perceived importance and perceived fulfillment is analyzed. Based on these values, it is tested whether there are statistically significant differences between the evaluation groups. One-Way-ANOVA test is used in parametric data sets with two or more independent groups. Therefore, significance test is performed with the One-Way-ANOVA test, as there are 3 independent evaluation groups are evaluated with an intermittent scale.

The significance test between 3 parametric data sets namely undergraduate students, graduate students and faculty members, are performed using the Statistical Package for the Social Sciences (SPSS). In total, 50 One-Way-ANOVA tests are performed for 25 sub-criteria under the perceived importance level and perceived fulfillment evaluation subjects. Respondent groups are taken as grouping variable. As a test variable, each of the 25 sub-criteria is tested one by one. $p$ value is taken as 0.05 ($p < 0.05$).

After the data sets are entered into SPSS, One-Way-ANOVA tests are performed separately for both evaluation subjects. There is no significant difference between the evaluation groups in the criteria with a sigma value greater than 0.05. There are significant differences between the groups for the sub-criteria whose significance values are less than 0.05. In order to see between which group data is causing the difference, Games-Howell post-hoc test is applied to the groups as the second step of the analysis. It is determined which group caused the differentiation from the post-hoc test results, in the pairwise comparison of:

- Undergraduate students - Graduate students,
- Undergraduate students - Faculty members,
- Graduate students - Faculty members.

Significance test results of perceived importance levels are given in Table 4.3, and significance test results of perceived fulfillment are given in Table 4.4.

Table 4.3 One-way ANOVA results for perceived importance levels of sub-criteria

| Sub-criteria | One Way ANOVA (p-values) | Post-hoc comparisons with Games–Howell test (p-values) | | | The group causing the difference |
|---|---|---|---|---|---|
| | | US vs GS | US vs FM | GS vs FM | |
| Familiarity | 0.08 | - | - | - | ns |
| Simplicity | 0.17 | - | - | - | ns |
| Ease of learning | 0.41 | - | - | - | ns |
| Self-descriptiveness | 0.35 | - | - | - | ns |
| Time behavior | **0.00** | **0.00** | **0.03** | 0.88 | US |
| Operability | 0.12 | - | - | - | ns |
| Loading time | **0.00** | **0.00** | **0.05** | 0.81 | US |
| Navigability | 0.23 | - | - | - | ns |
| Minimal action | 0.53 | - | - | - | ns |
| Feedback | *0.01* | *0.07* | *0.06* | *0.42* | § |
| Resource utilization | 0.37 | - | - | - | ns |
| Controllability | 0.15 | - | - | - | ns |
| Readability | 0.48 | - | - | - | ns |
| Minimal memory load | 0.61 | - | - | - | ns |
| Completeness | **0.00** | **0.00** | 0.07 | 0.86 | US |
| Consistency | **0.01** | **0.05** | 0.07 | 0.53 | US |
| Fault tolerance | **0.00** | **0.01** | **0.05** | 0.71 | US |
| Accuracy | *0.02* | *0.08* | *0.08* | *0.57* | *§* |
| Resource safety | 0.08 | - | - | - | ns |
| Attractiveness | **0.02** | **0.02** | 0.31 | 0.99 | US |
| Likeability | **0.00** | **0.00** | 0.19 | 0.99 | US |
| User guidance | **0.00** | **0.00** | 0.09 | 0.90 | US |
| Flexibility | 0.00 | 0.08 | **0.00** | **0.04** | FM |
| Privacy | 0.59 | - | - | - | ns |
| Security | **0.05** | **0.05** | 0.26 | 0.98 | US |

Bold p-values indicate significant differences between mean values of respondent groups at α=0.05
US: Undergraduate Students, GS: Graduate Students, FM: Faculty Members
ns: no significant differences are found
§: Significance in one-way ANOVA test, but non-significance in Games–Howell multiple pairwise comparisons

Table 4.4 One-way ANOVA results for perceived fulfillment levels of sub-criteria

| Sub-criteria | One Way ANOVA (p-values) | Post-hoc comparisons with Games–Howell test (p-values) | | | The group causing the difference |
|---|---|---|---|---|---|
| | | US vs GS | US vs FM | GS vs FM | |
| Familiarity | 0.16 | - | - | - | ns |
| Simplicity | 0.08 | - | - | - | ns |
| Ease of learning | 0.08 | - | - | - | ns |
| Self-descriptiveness | 0.15 | - | - | - | ns |
| Time behavior | 0.08 | - | - | - | ns |
| Operability | 0.21 | - | - | - | ns |
| Loading time | **0.00** | **0.00** | 0.70 | 0.22 | GS |
| Navigability | **0.02** | **0.01** | 0.99 | 0.15 | GS |
| Minimal action | **0.05** | 0.48 | 0.15 | **0.04** | FM |
| Feedback | **0.01** | **0.00** | 0.48 | 0.76 | US |
| Resource utilization | 0.18 | - | - | - | ns |
| Controllability | 0.35 | - | - | - | ns |
| Readability | 0.17 | - | - | - | ns |
| Minimal memory load | **0.02** | 0.73 | **0.03** | **0.01** | FM |
| Completeness | **0.00** | **0.00** | 0.59 | 0.50 | GS |
| Consistency | **0.00** | **0.00** | 0.96 | **0.04** | GS |
| Fault tolerance | 0.09 | - | - | - | ns |
| Accuracy | **0.00** | **0.00** | 0.30 | 0.43 | US |
| Resource safety | **0.02** | **0.01** | 0.99 | 0.15 | GS |
| Attractiveness | **0.01** | **0.01** | 0.99 | 0.18 | GS |
| Likeability | **0.01** | **0.01** | 0.99 | 0.20 | GS |
| User guidance | **0.01** | **0.00** | 0.97 | 0.20 | GS |
| Flexibility | 0.07 | - | - | - | ns |
| Privacy | **0.01** | **0.01** | 0.45 | **0.01** | GS |
| Security | **0.00** | **0.00** | 0.81 | **0.03** | GS |

Bold p-values indicate significant differences between mean values of respondent groups at α=0.05
US: Undergraduate Students, GS: Graduate Students, FM: Faculty Members
ns: no significant differences are found
§: Significance in one-way ANOVA test, but non-significance in Games–Howell multiple pairwise comparisons

As can be seen from the significance level test results, there is statistically significant difference between responses of evaluation groups for almost half of the sub-criteria. A subgroup that caused differentiation is encountered in 10 of 25 criteria in perceived importance. In terms of perceived fulfillment, an evaluation group in 14 of 25 criteria caused a significant differentiation. It is seen that the differentiation in 9 of 10 criteria in perceived importance test results is realized by undergraduate students and the other evaluation group that differs in 1 sub-criteria is faculty members. According to the perceived fulfillment test results, it is determined that the differentiation in 10 of the 14 sub-criteria is realized by graduate students and it is followed by faculty members and undergraduate students, 2 sub-criteria for each. Graduate students and undergraduate students are the two evaluation groups with the highest participation in the questionnaire. It is also seen in Table 4.1 that there is a big difference between the number of participants. Therefore, the detection of such differences in almost half of the sub-criteria shows that the data are reliable.

For example, it is seem that in the perceived importance level ANOVA test, Time behavior sub-criteria p-value is below 0.05, which means that there can be a statistically significant difference between the evaluation groups. In order to determine which evaluation group is causing the difference, Games-Howell post-hoc test is applied. Regarding to the test results, a significant difference found between undergraduate students-graduate students and undergraduate students-faculty members. This shows that the evaluation group that causes the difference is undergraduate students. Here, there are cases that although it has a significant difference in the ANOVA test, do not appear significantly different in multiple pairwises. Regarding to XLSTAT (https://help.xlstat.com/tutorial-guides/modeling-data/anova), it has been explained that there may be several reasons for this situation, such as groups with small sizes and p-value of the ANOVA table is very close to the significance level.

According to these results, it is concluded that each evaluation group should be analyzed separately, since there are groups that cause differentiation in almost half of the criteria. Therefore, the criteria weights of each group will be calculated separately and Axiomatic Design Procedure will be applied separately for each evaluation group.

### *4.2.3 Calculation of Criterion Weights with The Analytic Hierarchy Process*

Analytic Hierarchy Process (AHP) is one of the most frequently used methods in decision making processes, proposed by Saaty (1980). It enables decision making in situations where multiple criteria are present, taking into account the priorities of the decision maker. The decision goal is achieved by converting the qualitative data of the decision maker into quantitative values. It has a hierarchical structure consisting of decision goal, criteria and alternatives. In order to apply the AHP, firstly, the hierarchical structure is established and the decision goal is determined. Pairwise comparisons of criteria are made by the decision maker using Saaty's (1980) 1-9 scale. Thus, the complex hierarchical structure is transformed into comparison matrices of each of the criteria with respect to each other. Afterwards, in order to calculate the local and general weights, the eigenvector method is used at every level of the hierarchy. The weights of the alternatives on the basis of each criterion are multiplied by the weights of the criteria and the sum of these weights of each alternative is obtained. Finally, ranking of alternatives according to criteria is obtained.

AHP may vary in the literature due to the fact that the hierarchical structure elements it contains can vary, the variety of purposes and the use in combination with different methods. The decision goal is usually to find an answer to the question of which alternative to choose by ranking the solutions. In the literature, in LMS evaluations, AHP has generally been used to make a selection among various LMS alternatives in line with the criteria they have determined. For example, Delgado et al. (2020) used AHP to find the best LMS after Covid 19. They found Moodle as the most suitable LMS among Moodle, Chamilo and Google Classroom. With the same goal Srdevic et al. (2012), created a similar hierarchical structure of 5 levels in total, including decision goal, criteria with two lower levels, and alternatives. They compared the results of both methods by applying DeXi evaluation in addition to AHP. They found the most applicable LMS as Clix 5.0 among three alternative LMSs as Clix 5.0, Blackboard 6 and Moodle 1.5.2.

Petrova (2019), using the fuzzy AHP method, used a model with nine criteria, three alternatives, the decision goal of which is to choose the best LMS. She determined the most important criteria by finding the criteria weights and she also found NTEL LMS as the best LMS among NTEL, Sakai and Moodle. Ozcan & Emiroglu (2020) also created a model in line with the Fuzzy AHP method proposed by Chang (1996), in order to free the decision-making process from the judgments of the decision makers, unlike the methods mentioned. They made pairwise comparisons using triangular fuzzy numbers. At the end of the study, among cloud-based LMS alternatives Docebo, iSpring Learn, TalentLMS, 360learning, LatitudeLearning and Litmos, TalentLMS gave the best result. Radwan et al. (2016) made a choice of LMS using the Neutrosophic AHP method, which better reflects human thinking under uncertainty, unlike the basic AHP method. They concluded that Moodle LMS is the most suitable LMS among Moodle, Sakai, Atutor, ILIAS and Dokeos according to five main-criteria and 6 sub-criteria.

Altun et al. (2019) used three methods as fuzzy AHP, fuzzy TOPSIS, and an integrated model of fuzzy AHP+TOPSIS, to decide the best LMS. The same hierarchical structure in all three methods; criteria, sub-criteria and six LMS alternatives are used as Atutor, Claroline, Sakai, Moodle, OLAT, Dokeos. In the integrated model, the criteria weights obtained from the fuzzy AHP method are used to find the ranking of the alternatives in the fuzzy TOPSIS method. According to the results of all three methods, they found Moodle LMS as the best alternative, as the best criteria content management and development are found. Sudaryono et al. (2020), did not set their decision goals as LMS selection in the AHP method, and presented a non-subjective method to teachers by ranking the students who provided their activities through LMS under 4 criteria.

In this study, since the criteria is not of equal importance by the evaluators, the weight of each criterion is found. Thus, the answer to the question of which criteria is more important for system users is found. The criteria weights calculated with the AHP, are later included in the ADP.

By making a rating on a 9-point scale among the criteria, it is possible to compare the qualitative parameters with each other in a quantitative sense. With this approach; in the third part of the questionnaire, a scale from 1 to 9, including pairwise comparisons of respondents on the main criteria is presented. For example, in a comparison of which of the Learnability and Efficiency main criteria is more important; for a score of 9, which is given closer to the Learnability criteria, the Learnability score is taken as 9 and accordingly the Efficiency score is taken as 1 over

9. What is aimed with this scale and AHP is to determine the weights of the criteria to be used in the ADP in the later stages of the study.

For each pairwise criteria comparison made by the respondents, the geometric mean of the ratings is taken. These geometric means are placed in a 5-by-5 matrix of criteria in accordance with AHP. In the previous section, the significance level of each sub-criterion is calculated and it is concluded that each group would be evaluated differently, since there is no negligible differences between the groups. Therefore, in this section, AHP is applied to each group separately and criteria weights are calculated separately for each group. The aggregated pairwise comparison matrices for all the evaluation groups are can be seen in the Table 4.5.

Table 4.5 Aggregated pairwise comparison matrices

| | *Main criteria* | Learnability | Efficiency | Memorability | Errors | Satisfaction |
|---|---|---|---|---|---|---|
| Under-graduate students | Learnability | 1 | 1.09 | 1.82 | 0.72 | 1.25 |
| | Efficiency | 1/1.09 | 1 | 2.84 | 0.98 | 2.03 |
| | Memorability | 1/1.82 | 1/2.84 | 1 | 0.64 | 1.04 |
| | Errors | 1/0.72 | 1/0.98 | 1/0.64 | 1 | 2.68 |
| | Satisfaction | 1/1.25 | 1/2.03 | 1/1.04 | 1/2.68 | 1 |
| Graduate students | Learnability | 1 | 1.04 | 3.05 | 0.66 | 1.74 |
| | Efficiency | 1/1.04 | 1 | 3.25 | 0.80 | 2.50 |
| | Memorability | 1/3.05 | 1/3.25 | 1 | 0.47 | 0.82 |
| | Errors | 1/0.66 | 1/0.80 | 1/0.47 | 1 | 3.56 |
| | Satisfaction | 1/1.74 | 1/2.50 | 1/0.82 | 1/3.56 | 1 |
| Faculty members | Learnability | 1 | 0.90 | 3.18 | 0.86 | 1.43 |
| | Efficiency | 1/0.90 | 1 | 2.17 | 0.58 | 1.31 |
| | Memorability | 1/3.18 | 1/2.17 | 1 | 0.39 | 0.81 |
| | Errors | 1/0.86 | 1/0.58 | 1/0.39 | 1 | 2.69 |
| | Satisfaction | 1/1.43 | 1/1.31 | 1/0.81 | 1/2.69 | 1 |

Afterwards, this matrix is normalized and the main criteria weights for all the evaluation groups are found as in the Table 4.6. According to all evaluation groups; it has been determined that learnability, efficiency and errors main criteria are more weighted than memorability and satisfaction main criteria.

Table 4.6 Main evaluation criteria weights for respondent groups

| Evaluation group | Main evaluation criteria weights | | | | |
|---|---|---|---|---|---|
| | Learnability | Efficiency | Memorability | Errors | Satisfaction |
| Undergraduate students | 0.21 | 0.26 | 0.13 | 0.27 | 0.13 |
| Graduate students | 0.23 | 0.26 | 0.10 | 0.31 | 0.11 |
| Faculty members | 0.24 | 0.21 | 0.10 | 0.31 | 0.14 |

After determining the criterion weights, a consistency test was performed to determine whether these calculated criteria weights are consistent. The Random Index (RI) value for a 5-dimensional matrix is taken as 1.12 according to the Table 4.7.

Table 4.7 The Random Index (RI) values by matrix size

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.48 |

Necessary operations are made and it is concluded that all of the aggregated pairwise comparison matrices are consistent, by the Consistency Ratio (CR) values of the matrices are less than 0.1. Consistency Ratio (CR) values found are shown in Table 4.8.

Table 4.8 Consistency Ratio (CR) values

| **Evaluation group** | **CR Values** |
|---|---|
| Undergraduate students | 0.03 |
| Graduate students | 0.02 |
| Faculty members | 0.01 |

### *4.2.4 Axiomatic Design Method*

In this study, Axiomatic Design Procedure (ADP) is used to evaluate the perceived usability of SAKAI LMS. So far; the perceived importance levels and the perceived fulfillment levels are collected. Descriptive statistics and main criteria weights are calculated. For the reasons mentioned earlier, the perceived usability of a system can be easily evaluated with ADP.

ADP is a Multiple Criteria Decision Making method (MCDM) developed by Suh (2001). It has a structure that can evaluate both quantitative and qualitative data together. Two basic axioms are accepted, namely axiom of independence and axiom of knowledge. The independence of the evaluation criteria between each other is accepted by the axiom of independence. In other words, an alternative system design that meets all of the independent functional needs provides the independence axiom. In this study, the evaluation criteria are considered independent from each other as the related studies in the literature (e.g. Dubey et al., 2012). Among the alternatives that provide the independence axiom, it is accepted as the best viable solution with minimum information content $(I_j)$ by the axiom of knowledge (Suh, 2001). The information content $(I_j)$ is calculated as in Equation 4.5, 4.6, with $p_j$, which expresses the probability of success in meeting the current functional requirement.

With information about the system and design ranges for the functional requirements (i.e. Evaluation Criteria, EC), there is a probability density function, $f(EC_j)$ for any $EC_j$. According to Suh (2001); where $EC_j$ is a continuous random variable, probability $(p_j)$ of satisfying the $EC_j$ in terms of its lower and upper bounded desired range $[dr^l, dr^u]$ can be computed by using Equation 4.3.

$$p_j = \int_{dr^l}^{dr^u} f(EC_j)\, dEC_j \tag{4.3}$$

Axiomatic Design has two main concepts as system range and design range which gives the probability of achievement for the $EC_j$. Design range represents user's expectations from the system to accomplish (i.e., desired range, $[dr^l, dr^u]$). System range represents what the system is able to deliver $[sr^l, sr^u]$. The common area (i.e., common range, $(sr^u - dr^l)$) where both ranges intersect, represents how much of the system actually meets these expectations on the basis of evaluation criteria. Figure 4.2 shows the common range which is a viable solution in ADP.

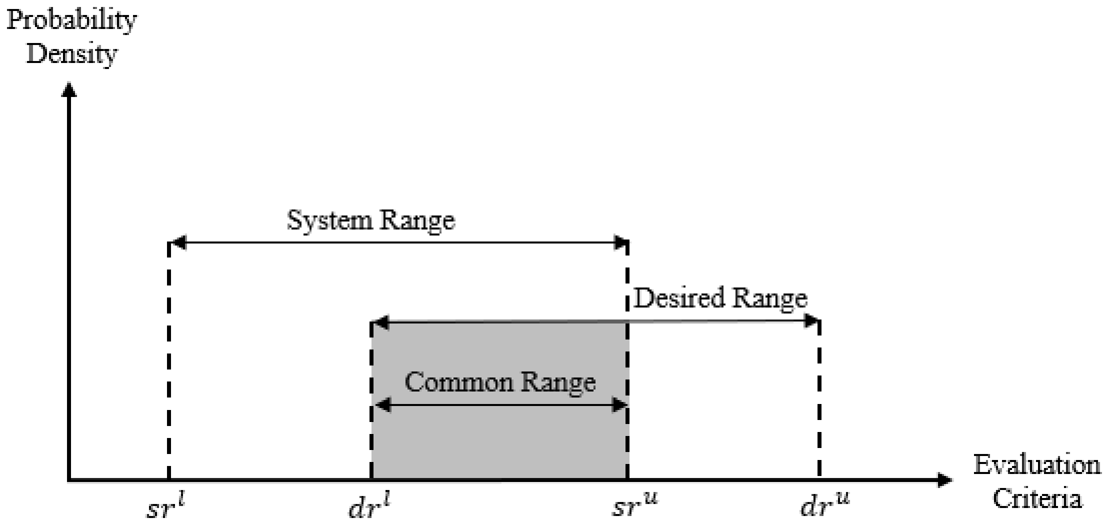


Figure 4.2 Desired, system and common ranges in case of a uniform probability density function of an EC

Interval values for the desired and system ranges are considered consequently uniform distribution for ECs are used. For this reason, Equation 4.3 is transformed to Equation 4.4. Accordingly, $p$, which expresses the probability of meeting the functional requirements, is calculated as in Equation 4.4.

$$p_j = \frac{common\ range}{system\ range} \tag{4.4}$$

Information content $(I_j)$ is calculated as in Equation 4.5 or Equation 4.6 with $p_j$, which expresses the probability of fulfilling a given $EC_j$.

$$I_j = log_2(\frac{1}{p_j}) \tag{4.5}$$

$$I_j = log_2(\frac{system\ range}{common\ range}) \tag{4.6}$$

In case of more than one functional requirement (in this case $EC_{j...N}$), the overall information content, $I_o$, can be computed by summing information content of each $EC_j$ $(j \in N)$ by Equation 4.7 (Kulak, 2004). For the purposes of this study, $I_o$, denotes perceived usability of LMS.

$$I_o = \sum_{j=1}^{N} I_j \tag{4.7}$$

When probability of satisfaction of an $EC_j$ is equal to zero, $I_o$ will be infinity. In this case, they are rejected because the system range values of the relevant criteria do not intersect with the design range values (Suh, 1995). In case of perfect satisfaction with minimal information content, all of the satisfaction probabilities are equal to one, which makes $I_o$ equals to zero.

In the perceived usability evaluation of the SAKAI LMS, criterion weights $(w_j)$ are not considered equal as in Equation 4.7 and criterion weights are included in ADP. Weights $w_j$, that represents the importance levels of the main criteria are obtained by applying AHP to the data obtained from the pairwise comparison section of the questionnaire. The calculated main criteria weights are taken from the Table 4.6. Weighted overall information content, $I_o$, is calculated by using Equations 4.8 and 4.9.

$$I_j^w = \begin{cases} \left[log_2\left(\frac{1}{p_j}\right)\right]^{1/w_j} & 0 \le I_j < 1 \\ \left[log_2\left(\frac{1}{p_j}\right)\right]^{w_j} & I_j > 1 \\ w_j & I_j = 1 \end{cases} \tag{4.8}$$

$$I_o^w = \sum_{j=1}^{N} I_j^w \tag{4.9}$$

In order to obtain the system range, the second and fourth parts of the questionnaire are utilized, in which the perceived importance and perceived fulfillment levels of the sub-criteria evaluated. Satisfaction scores for the main-criteria of each system user are calculated by multiplying the criteria fulfillment levels of SAKAI LMS with the normalized perceived importance data for each sub-criteria under the related main criterion. This procedure is similar to the simple additive weighting method as it aggregates each sub-criteria under the relevant main criterion.

For example, the ‘learnability’ main criterion has 4 sub-criteria as ‘familiarity’, ‘simplicity’, ‘ease of learning’ and ‘self-descriptiveness’. By a system user in the relevant questionnaires for each sub-criterion, let the perceived importance values be rated as 4, 3, 4, 4 and the perceived fulfillment values as 3, 3, 4, 3. First of all, the perceived importance for this user is normalized as 4/15, 3/15, 4/15, 4/15 that is 0.266, 0.2, 0.266, 0.266. Afterwards, the normalized perceived importance values are multiplied by the perceived fulfillment values. Thus, the satisfaction score for the learnability main criterion is obtained as 0.266*3+0.2*3+0.266*4+0.266*3=3.26.

This procedure is repeated for each main criteria, each system user, and each respondent group. In order to determine the system ranges, standard deviation, $\sigma$, values are added and subtracted from the mean, $\mu$, values $[sr_j^l = \mu_j - \sigma_j,\ sr_j^u = \mu_j + \sigma_j]$. Table 4.9 presents system ranges for the main criteria for respondent groups.

As it can be seen in Table 4.9, all main criteria have a common range on the basis of all evaluation groups. Satisfaction of the result obtained, depends on the common range area. Small overlaps will result in not getting a qualified result due to smaller satisfaction levels. In other words, the fact that there is a common range for all main criteria does not mean that all of them bring qualified results in terms of perceived usability.

Table 4.9 System ranges

| | | Respondent groups | | |
|---|---|---|---|---|
| | | Undergraduate students | Graduate students | Faculty members |
| Learnability | $\mu$ ; $\sigma$ | 3.61 ; 0.74 | 3.69 ; 0.67 | 3.25 ; 1.09 |
| | $sr^l$ ; $sr^u$ | 2.87 ; 4.35 | 3.02 ; 4.36 | 2.16 ; 4.34 |
| Efficiency | $\mu$ ; $\sigma$ | 3.11 ; 0.84 | 3.47 ; 0.60 | 3.02 ; 0.79 |
| | $sr^l$ ; $sr^u$ | 2.27 ; 3.95 | 2.87 ; 4.07 | 2.23 ; 3.81 |
| Memorability | $\mu$ ; $\sigma$ | 3.55 ; 0.80 | 3.63 ; 0.80 | 3.10 ; 0.93 |
| | $sr^l$ ; $sr^u$ | 2.75 ; 4.35 | 2.83 ; 4.43 | 2.17 ; 4.03 |
| Errors | $\mu$ ; $\sigma$ | 2.68 ; 0.73 | 3.19 ; 0.69 | 2.79 ; 0.69 |
| | $sr^l$ ; $sr^u$ | 1.95 ; 3.41 | 2.50 ; 3.88 | 2.10 ; 3.48 |
| Satisfaction | $\mu$ ; $\sigma$ | 2.91 ; 0.72 | 3.35 ; 0.65 | 2.76 ; 0.81 |
| | $sr^l$ ; $sr^u$ | 2.19 ; 3.63 | 2.70 ; 4.00 | 1.95 ; 3.57 |

On the other hand, the design range values for all the main criteria are set to $[dr^l = 3, dr^u = 5]$, assuming the system mean and above-mean are acceptable ranges, in this study. The common area where both design and system ranges intersect represents how much of SAKAI actually meets these expectations on the basis of each criteria. To find this common area, information contents are needed. Weighted information content for each EC and weighted overall information content of each respondent group are computed via Equations 4.8 and 4.9 and depicted in Table 4.10. As mentioned before, the weights of the main criteria used in this equation are calculated by using the AHP.

Table 4.10 Weighted information contents values for respondent groups

| Respondent groups | Information Contents for EC | | | | | |
|---|---|---|---|---|---|---|
| | Learnability | Efficiency | Memorability | Errors | Satisfaction | OIC* |
| Undergraduate students | 0.00007431 | 0.4759 | 0.000014379 | 1.1778 | 1.0228 | 2.6766 |
| Graduate students | 0.0000 | 0.0009035 | ≅ 0 | 0.2465 | 0.000117234 | 0.2475 |
| Faculty members | 0.2291 | 0.8395 | 0.2031 | 1.1394 | 1.0591 | 3.4702 |

* Overall Information Content

As an example according to Equation 4.6, learnability information content of undergraduate students (i.e. $I(learnability)_{undergraduate\ students}$) is calculated as;

$$I(learnability)_{undergraduate\ students} = log_2\left(\frac{4.35-2.87}{4.35-3}\right) = 0.1326 < 1,$$

$$I(learnability)_{undergraduate\ students} = 0.1326^{\frac{1}{0.21}} = 0.00007431$$

As it can be seen from the results, with a value of 0.2475, the OIC of graduate students is the lowest compared to undergraduate students and faculty members. As mentioned before, the perceived usability level of SAKAI LMS of graduate students can be considered as the best result, as they have the minimum information content. The best result in this study means that the perceived usability level of SAKAI LMS is the highest. Graduate students are followed by undergraduate students with a value of 2.6766, while undergraduate students are followed by faculty members with a value of 3.4702.

According to the realized ranking, faculty members is the group whose expectations from the system are met the least in the perceived usability evaluation of the SAKAI LMS. This can be explained by the result of the analysis in which the knowledge levels of the evaluation groups measured in the previous sections about the LMS. According to the results of this analysis, faculty members are the group with the highest level of knowledge on LMS, compared to other evaluation groups. In parallel with this, the faculty members are the group that uses the system the most. It can be said that; in the perceived usability evaluation of the SAKAI, faculty members are the group whose expectations from the system are the least met due to their high level of interaction with the system and their high level of knowledge about LMS. Based on this, it is reasonable that graduate students, who have the least interaction with the system and have much less knowledge of LMS than faculty members, are the group whose expectations from the system are met the most.

The order of the main criteria that meets the undergraduate student’s expectations the most, with the information content value from small to large, is as follows:

Learnability = Memorability > Efficiency > Satisfaction > Errors

The order of the criteria that meets the graduate student's expectations the most, with the information content value from small to large, is as follows:

Learnability = Memorability = Efficiency = Satisfaction > Errors

The order of the criteria that meets the faculty member's expectations the most, with the information content value from small to large, is as follows:

Memorability > Learnability > Efficiency > Satisfaction > Errors

Considering the information content ranking in terms of main criteria, it can be seen that the rankings of the criteria are very similar on the basis of each evaluation group. This parallel ranking of the evaluation criteria, shows that the collected data are reliable. Therefore, these ranking sheds light on the criteria to be considered in the development of the SAKAI LMS being used. According to the ranking of each evaluation group; efficiency, satisfaction and errors criteria are in the last three of the rankings. Development studies can be carried out on the basis of these main criteria and their sub-criteria for the LMS being used.

When the results are examined in terms of evaluation criteria, learnability and memorability EC have the smallest information content among all EC for all respondent groups. Consequently, it can be said that all users find SAKAI LMS easy to learn and perform the necessary operations with less mental effort. For all evaluation groups (especially undergraduate students and faculty members), errors EC appears to have the highest information content value. This shows that all users find SAKAI LMS less usable in terms of accuracy, completeness, consistency, fault tolerance and resource safety sub-criteria. When the criteria and overall information content values are evaluated together, it is seen that graduate students find SAKAI LMS more usable contrary to other evaluation groups.

# CHAPTER 5
# DISCUSSION AND CONCLUSIONS

Within the scope of this study, perceived usability evaluation of SAKAI-LMS, which is in use at an educational organization is made. Contrary to the decision-making phase of which LMS to use in related studies in literature, the perceived usability of the currently used system is evaluated. A comprehensive review in the literature on usability evaluation methodologies of LMSs has been made. The place of concepts and phenomena in the literature such as; the relationship between software development life cycle and usability, the usage areas of LMS, studies in the literature on LMS usability evaluations, the perceived dimension of the usability concept are analyzed. Usability criteria and methods that would enable the LMS perceived usability evaluation in the best way are investigated. After a detailed literature review, a new Axiomatic Design Procedure based approach on a real life case study is developed in order to evaluate perceived usability of Learning Management Systems.

Learning Management System usability criteria (main criteria as; learnability, efficiency, memorability, errors, satisfaction) and study methodology are determined through a detailed literature review. Among the questionnaire scales in the literature, SUS, which has a higher validity and reliability value than the others, and best expresses the perceived dimension of usability, is selected. A SUS based questionnaire is created to collect the perceived importance and perceived fulfillment information of the determined criteria and their pairwise comparison data. The questionnaire is directed to system users, namely faculty members, graduate students and undergraduate students. Detailed statistical analyzes are applied to the collected data. The lower and upper limits of the perceived importance and fulfillment values are determined on the basis of each criterion. Significance test are used to investigate whether the obtained data is significant and it is found that the data is reliable.

The criteria weights are calculated by applying the Analytic Hierarchy Process to the pairwise comparison data of the criteria, collected through the questionnaire. According to the result obtained from the Significance test, separate AHP is applied to each evaluation group. Finally, Axiomatic Design Procedure, one of the Multiple Criteria Decision Making methods, is used for the first time in the literature for LMS usability evaluation. The criterion weights obtained from the AHP are included in the ADP. Perceived usability of the customized SAKAI Learning Management System is found satisfactory based on the developed approach. When the perceived usability values are examined, it is concluded that the SAKAI LMS perceived usability values of undergraduate students are the highest compared to other evaluation groups. Undergraduate students are followed by graduate students and faculty members, respectively. It is observed that the ranking on the basis of the main criteria is realized in a similar way in all evaluation groups. While SAKAI LMS got the highest usability values in all evaluation groups for learnability, memorability and efficiency criteria, it is seen that errors and satisfaction criteria had low usability values.

It is concluded that the proposed approach is easy to apply to practical circumstances and it is able to quantify perceived usability of Learning Management Systems. Also, it is seen that the data obtained from the designed questionnaire are reliable. As a future work, the proposed approach can also be extended to process fuzzy information by adopting the fuzzy Axiomatic Design Approaches. Moreover, it is also possible to compare perceived usability of alternative Learning Management Systems by utilizing the proposed approach. Thus, it is ensured that the best LMS is selected and adapted to organizations and institutes.

## REFERENCES


Abran, A., Khelifi, A., Suryn, W., & Seffah, A. (2004). Usability meanings and interpretations in ISO standards. *Software Quality Journal, 11*, 325-338.

Agarwal, R., & Prasad, J. (1999). Are individual differences Germane to the acceptance of new information technologies. *Decision Sciences, 30*, 361-391.

Al-Sofi, BBMA. (2021). Student satisfaction with e-learning using Blackboard LMS during the covid-19 circumstances: realities, expectations, and future prospects. *Pegem Journal of Education and Instruction, 11*(4), 265-281.

Altun Turker, Y., Baynal, K., & Turker, T. (2019). The evaluation of learning management systems by using fuzzy AHP, fuzzy TOPSIS and an integrated method: A case study. *Turkish Online Journal of Distance Education, ISSN 1302-6488, 20*(2), 195-218.

Alturki, U. & Aldraiweesh, A. (2021). Application of learning management system (LMS) during the covid-19 pandemic: a sustainable acceptance model of the expansion technology approach. *Sustainability, 13,* 10991. https://doi.org/10.3390/ su131910991

Alonso-Ríos, D., Vázquez-García, A., Mosqueira-Rey, E., & Moret-Bonillo, V. (2010). Usability: A critical analysis and a taxonomy. *International Journal of Human–Computer Interaction, 26,* 53 – 74.

Arsenyan, J., & Büyüközkan, G. (2014). Modelling collaborative product development using axiomatic design principles: application to software industry. *Production Planning & Control, 25*, 515 – 547.

Aybay, I. & Oguz, D. (2002). A learning management system developed at the Eastern Mediterranean University. *The Turkish Online Journal of Educational Technology*, *2*(2), 1303-652.

Battleson, B.L., Booth, A., & Weintrop, J. (2001). Usability testing of an academic library web site: a case study. *The Journal of Academic Librarianship*, *27*(3), 188-198.

Blecken, A., Brüggemann, D., & Marx, W. (2010). *Usability evaluation of a learning management system*. 43rd Hawaii International Conference on System Sciences, 1-9.

Boram, P. (2020, July 16). *(News Focus) After six months, pandemic accelerates arrival of contactless future in S. Korea.* Yna. https://en.yna.co.kr/view/AEN20200716002500315

Bouchrika, I. (2022, September 2). *51 LMS Statistics: 2021/2022 Data, Trends & Predictions*. Research. https://research.com/education/lms-statistics

Bouhnik, D. & Marcus, T. (2006). Interaction in distance-learning courses. *Journal of the American Society for Information Science and Technology*, *57*(3), 299–305.

Brinck, T., Gergle, D., & Wood, S.D. (2002). *Designing web sites that work: usability for the web*. Morgan Kaufmann, San Francisco.

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry*, *189*(194), 4–7. https://doi.org/10.1201/9781498710411-35

Chang, D. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, *95*, 649-655.

Chin, J.P., Diehl, V.A., & Norman, K.L. (1988). Development of an instrument measuring user satisfaction of the human-computer interface. *Computer-Human Interaction '88*.

Constantine, L.L., & Lockwood, L.A. (1999). *Software for use - a practical guide to the models and methods of usage-centered design*. Addison-Wesley, New York.

Cigdem, H. & Ozturk, M. (2016). Factors affecting students' behavioral intention to use LMS at a Turkish post-secondary vocational school. *International Review of Research in Open and Distributed Learning, 17*(3), 276-295.

Çelik, K., Pehlivanoğlu, H., E., Avcı, S., & Aladağ, Z. (2020). Aksiyomlarla tasarim yöntemi ile genleştirilmiş polistiren sert köpük boncuk hammaddesi seçimi. *Journal of Industrial Engineering, 31*(0), 32-43.

Davis, F.D., Bagozzi, R.P., & Warshaw, P.R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management Science, 35*, 982-1003.

Delgado, A., Huamaní, E.L., Obispo-Mego, H., & Justo-López, D. (2020). Analysis of web platforms of learning management systems for distance education in the face of social isolation. *International Journal of Advanced Trends in Computer Science and Engineering, 9*(5), 7986 – 7991.

Doll, W. J., Hendrickson, A., & Deng. X. (1998). Using Davis's perceived usefulness and ease-of-use instruments for decision making: a confirmatory and multigroup invariance analysis. *Decision Sciences, 29*(4), 839-869.

Donyaee, M., & Seffah, A. (2001). *Quim: an integrated model for specifying and measuring quality in use*. In: Eighth IFIP Conference on Human Computer Interaction, Tokyo, Japan.

Dubey, S. K., Gulati, A., & Rana, A. (2012a). Integrated model for software usability. *International Journal on Computer Science and Engineering (IJCSE), 4*(3), 429-437.

Dubey, S. K., Gulati, A., & Rana, A. (2012b). Usability evaluation of software systems using fuzzy multi criteria approach. *International Journal of Computer Science Issues*, *9*(2), 404-409.

Elliott, R., & Boshoff, C. (2007). The influence of the owner-manager of small tourism businesses on the success of internet marketing. *South African Journal of Business Management*, *38*(3), 15-27. https://doi.org/10.4102/sajbm.v38i3.585

Epping, R.J. (2010). Innovative use of Blackboard to assess laboratory skills. *Journal of Learning Design*, *3*(3), 32-36.

Finstad, K. (2010). The usability metric for user experience. *Interacting with Computers, 22*, 323–327. doi:10.1016/j.intcom.2010.04.004

Frojkaer, E., Hertzum, M., & Hornbaek, K. (2000). Measuring usability: are effectiveness, efficiency and satisfaction really correlated. *ACM Press CHI*, 345–352.

Guo, Y. (2014). The axiomatic usability evaluation method. In K. Blashki, & P. Isaias (Eds.), Emerging Research and Trends in Interactivity and the Human-Computer Interface 353-373. IGI Global. https://doi.org/10.4018/978-1-4666-4623-0.ch018

Gupta, D., & Khanna, A. (2017). Software usability datasets. *International Journal of Pure and Applied Mathematics*, *117*(15), 1001-1014.

Güngör, F. (2017). Sızdırmaz conta malzemesinin aksiyomatik tasarım medoduyla seçilmesi. *El-Cezerî Journal of Science and Engineering*, *4*(1), 1-10.

Harrison, R., Flood, D., & Duce, D. (2013). Usability of mobile applications: literature review and rationale for a new usability model. *Journal of Interaction Science, 1*, 1-16.

Hirval & Zaim, M. (2021). The usability of learning management system (LMS) and students' perception in English language teaching at SMKN 2 Padang. *Advances in Social Science, Education and Humanities Research*, *579*, 88-93.

International Organization for Standardization. (2011). *Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality models* (ISO/IEC Standard No. 25010:2011). https://www.iso.org/standard/35733.html

International Organization for Standardization. (2017). *Systems and software engineering - Software life cycle processes* (ISO/IEC/IEEE Standard No. 12207:2017). https://www.iso.org/standard/63712.html

International Organization for Standardization. (2018). *Ergonomics of human-system interaction - Part 11: Usability: definitions and concepts* (ISO Standard No. 9241-11:2018). https://www.iso.org/standard/63500.html

Kakasevski, G., Mihajlov, M., Arsenovski, S., & Chungurski S. (2008). *Evaluating usability in learning management system Moodle.* Proceedings of the ITI 2008 30th Int. Conf. on Information Technology Interfaces.

Karataş, M., & Akman, G. (2009). Evaluation of innovative culture structure of the machine manufacturing firm by axiomatic design. *DPÜ Fen Bilimleri Enstitüsü Dergisi*, *20*, 45–62.

Kim, Y.J., Chun, J.U., & Song, J. (2009). Investigating the role of attitude in technology acceptance from an attitude strength perspective. *International*

*Journal of Information Management: The Journal for Information Professionals.*, *29*, 67-77.

Kirakowski, J., Claridge, N., & Whitehand, R. (1998). *Human centered measures of success in web site design*. Proceedings of 4th Conference on Human factors and the Web. Basking Ridge, NJ, USA.

Kulak, O., & Kahraman, C. (2004). Multi-attribute comparison of advanced manufacturing systems using fuzzy vs. crisp axiomatic design approach. *International Journal of Production Economics*, *95*, 415–424.

Kulak, O., & Kahraman, C. (2005). Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process. *Information Sciences 170*, 191–210.

Lewis, J. R. (1995). IBM computer usability satisfaction questionnaires: psychometric evaluation and instructions for use. *International Journal of Human-Computer Interaction*, *7*, 57–78. doi:10.1080/ 10447319509526110

Lewis, J. R. (2018a). The system usability scale: past, present, and future. *International Journal of Human-Computer Interaction*, *34*(7), 577–590. https://doi.org/10.1080/10447318.2018.1455307

Lin, H. F. (2007). Knowledge sharing and firm innovation capability: an empirical study. *International Journal of Manpower*, *28*, 315-332. https://doi.org/10.1108/01437720710755272

Lund, A.M. (2001). Measuring usability with the USE questionnaire. *Usability Interface,*. *8*(2).

Martin, L., Martinez, D.R., Revilla, O., Aguilar, M.J., Santos, O.C., Boticario, J.G. (2008). Usability in e-learning platforms: heuristics comparison between

Moodle, Sakai and dotLRN. *Proceedings of the Sixth International Conference on Community based environments*, 12-16.

Mathieson, K. (1991). Predicting user intentions: comparing the technology acceptance model with the theory of planned behavior. *Information Systems Research, 2*, 173-191.

Meiselwitz, G., & Sadera, W. A. (2008). Investigating the connection between usability and learning outcomes in online learning environments. *MERLOT Journal OF Online Learning and Teaching, 4* (2), 234-242.

Nielsen, J. (1993). Usability engineering. *London: Academic Press*.

Nielsen, J. (1993). What is usability? *Academic Press, Boston*.

Nielsen, J. (2012). Usability 101: *Introduction to usability*. Nngroup. https://www.nngroup.com/articles/usability-101-introduction-to-usability

Önaçan, M. B. K., & Ertürk, A. (2017). Usability evaluation of learning management system in a higher education institution: a scale development study. *Journal of Global Strategic Management*, *11*(1), 055-064.

Özcan, H., & Emiroğlu, B.G. (2020). Bulut tabanlı öğrenme yönetim sistemi seçiminde bulanık çok kriterli karar analizi yaklaşımı. *Bilişim Teknolojileri Dergisi*, *13*(1), 97-111. DOI: 10.17671/gazibtd.589757

Pal, D. & Vanijja, V. (2020). Perceived usability evaluation of Microsoft Teams as an online learning platform during covid-19 using system usability scale and technology acceptance model in India. *Children and Youth Services Review*, 119, 105535. https://doi.org/10.1016/j.childyouth.2020.105535

Petrova, V. (2019). Using the analytic hierarchy process for LMS selection. *Proceedings of the 20th International Conference on Computer Systems and Technologies*, 332-336. https://doi.org/10.1145/3345252.3345297

Pimentel, A.R., & Stadzisz, P.C. (2006). *A use case based object-oriented software design approach using the axiomatic design theory*. International Conference on Axiomatic Design.

Radwan, N.M., Senousy, M.B., & Riad, A.M. (2017). Neutrosophic AHP multi criteria decision making method applied on the selection of learning management system. *International Journal of Advancements in Computing Technology(IJACT), 8*(5), 95-105.

Rubin, J. (1994). A review of second language listening comprehension research. *The Modern Language Journal*, *78*(2), 199-221.

Saaty, T. (1980). The analytic hierarchy process. *McGraw-Hill International Book Company, USA.*

Sagar, K., & Saha, A. (2017). A systematic review of software usability studies. *International Journal of Information Technology,* 1-24.

Sauro, J. (2011). A practical guide to the system usability scale: background, benchmarks, & best practices. *Denver, CO: Measuring Usability LLC*.

Sauro, J., & Lewis, J. R. (2016). *Quantifying the user experience: practical statistics for user research.* Morgan Kaufmann.

Seffah, A., Donyaee, M., Kline, R. B., & Padda, H. K. (2006). Usability measurement and metrics: a consolidated model. *Software Quality Journal, 14,* 159–178.

Segars, A. H., & Grover V. (1993). Re-examining perceived ease of use and usefulness: a confirmatory factor analysis. *MIS Quarterly, 17*(4), 517-525.

Senol, L., Gecili, H., & Durdu, P. O. (2014). *Usability evaluation of a Moodle based learning management system*. EdMedia - Tampere, Finland.

Shackel, B. (1991). Usability - context, framework, definition, design and evaluation. In B. Shackel & S. Richardson (Eds.), *Human factors for informatics usability* (21–37). Cambridge, UK: Cambridge University Press.

Srdjevic, B., Pipan, M., Srdjevic, Z., & Arh, T. (2012). AHP supported evaluation of LMS quality. *I-UxSED*.

Subulan, K., & Baykasoğlu, A. (2021). An improved extension of weighted hierarchical fuzzy axiomatic design: sustainable route selection problem in intermodal transportation networks. *In Özceylan, Eren; M. Gupta, & Surendra (Eds.), Sustainable Production and Logistics, CRC Press.* 321-357.

Sudaryono, Rahardja, U., & Masaeni (2020). Decision support system for ranking of students in learning management system (LMS) activities using analytical hierarchy process (AHP) method. *Journal of Physics: Conference Series*, 1477. doi:10.1088/1742-6596/1477/2/022022.

Suh, N.P. (1995). Design and operation oflarge systems. *Annals of CIRP, 14* (3), 203–213.

Suh, N.P. (2001). Axiomatic design—advances and applications, *Oxford University Press, New York.*

Thuseethan, S., Achchuthan, S.& Kuhanesan, S. (2015). usability evaluation of learning management systems in Sri Lankan universities. *Global Journal of Computer Science and Technology: C Software & Data Engineering*, *15*(1).

Tullis, T. S., & Stetson, J. N. (2004). *A comparison of questionnaires for assessing website usability*. Proceedings of UPA 2004 Conference, Minneapolis, Minnesota.

UNESCO (2020). *Global monitoring of school closures caused by covid-19*. UNESCO. https://en.unesco.org/covid19/educationresponse

Viner, R.M., Russell, S.J., Croker, H., Packer, J., Ward, J., Stansfield, C., Mytton, O., Bonell, C., Booy, R. (2020). School closure and management practices during coronavirus outbreaks including covid-19: a rapid systematic review. *Lancet Child Adolesc. Health, 4*, 397–404.

Quesenbery, W. (2001). What does usability mean: looking beyond ease of use. *In: Proceedings of the 18th Annual Conference Society for Technical Communications*.

XLSTAT. *Tutorials and guides, how to interpret contradictory results between ANOVA and multiple pairwise comparisons?* XLSTAT. https://help.xlstat.com/tutorial-guides/modeling-data/anova

Zaharias, P., & Poulymenakou, A. (2009). Developing a usability evaluation method for e-learning applications: beyond functional usability. *International Journal of Human–Computer Interaction, 25*, 75 – 98.

# APPENDICES

## Appendix A

Table A.1 Questions on the perceived importance level of usability evaluation sub-criteria for SAKAI LMS (Part 2 of the questionnaire)

| Corresponding Sub-criteria | Statements in the Questionnaire |
|---|---|
| Familiarity | Having key/understandable features of electronic learning management systems |
| Simplicity | Having simple-to-use user interface by most of the people |
| Ease of learning | Easiness of learning the software |
| Self-descriptiveness | Quality of user support in finding/reaching the required items within software |
| Time behavior | Ability of the software to quickly perform the required operations |
| Operability | User effort needed to use/run the software |
| Loading time | Response time of the software in loading pages |
| Navigability | Easiness in navigation through the user interface |
| Minimal action | Reachability of the required pages with minimum number-of-steps |
| Feedback | Ability of the software to provide useful feedback |
| Resource utilization | Using acceptable amount of computer resources (CPU etc.) while performing operations |
| Controllability | Easiness in controlling/using the software |
| Readability | Quality of visual readability of user interfaces |
| Minimal memory load | Requiring minimal memory load when using the software |
| Completeness | Lack of system/network errors in software operations |
| Consistency | Consistency of user interfaces of the software |
| Fault tolerance | Fault tolerance of the software |
| Accuracy | Ability of the software to provide correct results to user demands |
| Resource safety | Ability of the software to provide secure storage/processing of resources |
| Attractiveness | Attractiveness of user interface design of the software |
| Likeability | Likeability (perceptions, feelings, and opinions) of the software |
| User guidance | Ability of the software to provide useful online help |
| Flexibility | Customization flexibility of the software |
| Privacy | Ability of the software to protect user information |
| Security | Ability of the software to prevent unauthorized access to data |

# Appendix B

Table A.2 Pairwise comparison matrix to determine weight for the main-criteria (Part 3 of the questionnaire)

| | *Absolute importance* | | *Demonstrated importance* | | *Strong importance* | | *Weak importance* | | *Equal importance* | | *Weak importance* | | *Strong importance* | | *Demonstrated importance* | | *Absolute importance* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Learnability | | | | | | | | | | | | | | | | | | Efficiency |
| Learnability | | | | | | | | | | | | | | | | | | Memorability |
| Learnability | | | | | | | | | | | | | | | | | | Errors |
| Learnability | | | | | | | | | | | | | | | | | | Satisfaction |
| Efficiency | | | | | | | | | | | | | | | | | | Memorability |
| Efficiency | | | | | | | | | | | | | | | | | | Errors |
| Efficiency | | | | | | | | | | | | | | | | | | Satisfaction |
| Memorability | | | | | | | | | | | | | | | | | | Errors |
| Memorability | | | | | | | | | | | | | | | | | | Satisfaction |
| Errors | | | | | | | | | | | | | | | | | | Satisfaction |

## Appendix C

Table A.3 Questions on the perceived fulfillment level of usability evaluation sub-criteria for SAKAI LMS (Part 4 of the questionnaire)

| Corresponding Sub-criteria | Statements in the Questionnaire |
|---|---|
| Familiarity | SAKAI LMS has key/understandable features of electronic learning management systems |
| Simplicity | SAKAI LMS has simple-to-use user interface by most of the people |
| Ease of learning | Learning SAKAI LMS is easy |
| Self-descriptiveness | SAKAI LMS provides good quality user support in finding/reaching the required items |
| Time behavior | SAKAI LMS enables me to quickly perform the required operations |
| Operability | I can easily use/run SAKAI LMS |
| Loading time | SAKAI LMS has quick response time in loading pages |
| Navigability | It is easy to navigate through SAKAI LMS interfaces |
| Minimal action | SAKAI LMS enables me to reach the required pages with minimum number-of-steps |
| Feedback | SAKAI LMS provides useful feedback when there is a problem |
| Resource utilization | SAKAI LMS uses acceptable amount of computer resources (CPU etc.) while performing operations |
| Controllability | Controlling/using SAKAI LMS is easy |
| Readability | Visual readability of SAKAI LMS user interfaces is good |
| Minimal memory load | SAKAI LMS requires minimal memory load when performing operations |
| Completeness | SAKAI LMS generates minimal system/network errors |
| Consistency | SAKAI LMS has consistent user interfaces |
| Fault tolerance | SAKAI LMS has good fault tolerance |
| Accuracy | SAKAI LMS provides correct results to user demands |
| Resource safety | SAKAI LMS provides secure storage/processing of resources |
| Attractiveness | SAKAI LMS has attractive user interface design |
| Likeability | Using SAKAI LMS is enjoyable |
| User guidance | SAKAI LMS provides useful online help |
| Flexibility | SAKAI LMS is flexible to customize |
| Privacy | SAKAI LMS protects user information |
| Security | SAKAI LMS prevents unauthorized access to data |