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PAPER

Information Systems Maintenance: Maintenance Factors for Information Systems with a Focus on Teaching and Learning

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ABSTRACT

This work deals with the maintenance of information systems—specifically, with the maintenance of information systems that have a focus on teaching and learning. Depending on the context of an information system, there are different influencing factors for the maintenance of these systems. This work clarifies how the maintenance activities and their influencing factors differ in an information system for teaching and learning from other information systems, or why some influencing factors are particularly more important. The first step is to understand what *maintenance* means, why there is a need for maintenance, and which maintenance strategies can be used. Finally, the defined factors of influencing the maintenance of information systems for teaching and learning are evaluated during interviews with experts in order to be able to determine their relevance. A further part of this document is the influence of the General Data Protection Regulation (GDPR) guidelines on information systems maintenance, which came into force on May 25, 2018. These guidelines of the GDPR affect a large part of all information systems that process data—in particular, the processing of personal data. The GDPR regulates, among other things, the rights and obligations of data processing.

KEYWORDS

information systems, teaching and learning, maintenance, GDPR

1 INTRODUCTION

The reason for this work is to figure out if there are any differences in maintenance of information systems based on the context within which the information system is operating. Maintenance activities can result in very high costs, which make it very important that the planned maintenance activities achieve the desired result; otherwise, it would be a waste of money and time. For planning efficient maintenance activities, it is needed to know what factors have an impact on the maintenance of an information system.

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For an information system that has a hundred thousand active users, compared with an information system with a user base of less than a hundred, maintenance effort to keep the system scalable is more import for the system with more users. The scalability factor is only one out of many factors that can have an impact for the maintenance.

This work answers the question of whether there are differences for the maintenance of information systems if they are operating in the context of teaching and learning.

2 RESEARCH DESIGN

The aim of this work is to evaluate what factors have an influence on the maintenance of information systems and how these factors differ between information systems for teaching and learning from other information systems.

This leads to the following research question for this work.

"How do the influencing factors for maintenance activities of information systems with a focus on teaching and learning differ from other information systems?"

To answer this question, this work is structured in three main parts.

1. At the beginning, through studying existing literature about maintenance, overall maintenance factors for information systems will be defined.
2. Next, these factors will be evaluated and based on the relevance for the maintenance of information systems, with a focus on teaching and learning systems. Following this a final identification of the influencing factors for the maintenance of this system will be made.
3. Finally, through interviews with maintenance experts on information systems for teaching and learning, the identified influencing factors will be rated based on the relevance for the maintenance of this systems.

As a result, influencing factors will be ranked according to relevance, which must be taken into account when maintaining information systems for teaching and learning so that maintenance can lead to the desired success.

3 MAINTENANCE OF INFORMATION SYSTEMS WITH A FOCUS ON TEACHING AND LEARNING

Information systems are a collection of hardware, software, data, human beings, and processes working together to achieve the goal to provide information for the needs of user groups. Compared with the first information systems, when these systems were mainly used in the context of archiving data, information systems nowadays have a much bigger impact for the daily life [1].

The information that is generated by an information system can be used to make decisions, automate processes, support communication and cooperation between different groups of people, as well as help to build knowledge. Information systems are available mainly through the internet and have a central data source.

To make sure that information systems are working stably and without issues, regularly maintenance of these systems is important. The term *maintenance* is defined by the *IEEE Standard Glossary of Software Engineering Terminology* as follows: "The process of modifying a software system or component after delivery to correct faults, improve performance of other attributes, or adapt to a changed environment" [2].

In the year 1976, different groups of maintenance were mentioned for the first time by Swanson [3], who named these maintenance groups as follows.

- corrective maintenance
- adaptive maintenance
- perfective maintenance

Preventive maintenance completed the groups after a bit of a delay. These 4 different groups are the basis for defining specific steps of software maintenance (Table 1).

Table 1. Software maintenance categorization [4]

	Corrections	Improvements
Reactive activities	corrective maintenance	adaptive maintenance
Proactive activities	preventive maintenance	perfective maintenance

3.1 Corrective maintenance

Corrective maintenance deals with occurrence and fixing of bugs/errors that were produced during the process of developing a piece of software. These errors usually occur within a system that is already used in a production environment by a group of users. The goal of the corrective maintenance is to fix errors based on prioritization and urgency. The urgency depends on the type of error. For example, the correction of a wrong text color is less urgent than fixing wrong amounts calculated for an invoice.

3.2 Adaptive maintenance

Whenever the environment of an information system changes, adaptive maintenance is needed so that the system works under the new circumstances as before [4].

There are 2 types of adaptive maintenance:

- professional adaptive maintenance
- technical adaptive maintenance

Professional adaptive maintenance is necessary for compliance with legal requirements, for example, the General Data Protection Regulation (GDPR) guidelines.

Technical adaptive maintenance reacts to technical changes. This can be a security adjustment of the underlying database layer, which makes it necessary to upgrade the version of the programming languages use, or switching to another programming language because the one currently used is not compatible anymore with other technologies.

3.3 Perfective maintenance

Perfecting maintenance concerns the continuous improvement of the system. Properties such as performance, maintainability, and reliability are the main focuses of perfective maintenance. These properties are also known as non-functional requirements. Technical debt is often the main reason for the need for the perfective

maintenance. Technical debts is mostly the result of tight schedules or a tight budget, which results in poor-quality code that will require reworking With these debts, the performance of the system gets worse over time and changes and adaptations are often very costly [4].

3.4 Preventive maintenance

Like corrective maintenance, the purpose of preventive maintenance is also fixing bugs within an already-used system. The difference is the need to find bugs and errors *before* the users notice them. Table 1 shows that preventive maintenance deals with proactive corrections.

4 NEED FOR MAINTENANCE OF INFORMATION SYSTEMS

Information systems nowadays play a critical role for processes within an organization. An information system used within a hospital, for instance, is part of the daily working routines for administrative staff, like nurses and doctors. Each of these groups relies on a hospital information system to do its job as well as possible. The hospital information system needs to be reliable and efficient and to run safely. This also applies to other information systems, such as an information system for teaching and learning. For the users, it is extremely important that the system is reliable because the users need it often only for a specific period of time, such as the days before an exam.

The following paragraphs discuss in detail a few reasons why maintenance of information systems is needed.

4.1 Avoidance

Technologies are constantly evolving, but this evolution does not bring only advantages. It is possible that problems and vulnerabilities will occur through this process. Regular maintenance supports the avoidance and fixing of these possible software and hardware issues.

4.2 Compatibility

Through maintenance activities, it is also possible to help guarantee that any technologies used together stay compatible to each other. Technologies often have a passive dependence on other technologies. The operating system, for example, includes passive dependence by an information system. If the operating system is not up–to date, this can have a negative impact on the information system, which is built on top of the operating system [5].

4.3 Data security

Information systems process and store a large amount of data. It is essential that the data does not get lost under any circumstances and that sensitive data is

protected from unauthorized access. Regular maintenance is one chance to support data security. Outdated technologies increase the risk of unauthorized access; also, scheduled backup of the data can be affected if maintenance is not done.

4.4 Efficiency

The performance and efficiency of an information system also benefit from maintenance activities. System performance can get worse due to a higher frequency of active users. Obsolete system components can have also a negative impact on the system. Optimization through maintenance can guarantee and improve performance and efficiency.

4.5 Availability and longevity

Availability is a key factor for an information system. Different information systems may have a higher or lower demand for availability. At the end of the day, it is essential that users have access to an information system at the time they need it. In the context of a hospital information system, the availability can have an impact on life and death. Availability and longevity increase if maintenance activities are done regularly. Over the long run, the costs of maintenance will decrease if maintenance is done regularly instead of doing it only once a year [6].

5 SUCCESS FACTORS FOR THE MAINTENANCE OF INFORMATION SYSTEMS

Even if information systems are regularly maintained, it is not guaranteed that the maintenance activities will meet the requirements of the organization. Brössler et al. did a study to define some factors to evaluate the success of maintenance activities, which are discussed in the following paragraphs [7].

5.1 Functionality

Essential to any type of maintenance is that the system or service that is maintained does not lose continuity during the maintenance [8]. Users should not notice any losses of functionality due to maintenance activities. After the maintenance activities are done, the system should behave as before.

5.2 Quality

The system quality is an important indicator for the success of maintenance. Through preventive maintenance, known bugs are fixed to increase the software quality before the users are aware of the bugs. Metrics such as *error rate*, *performance*, and *code quality* are indicators to measure if the quality improved or deteriorated after maintenance.

5.3 Complexity

Depending on their scope, information systems have different levels of complexity, which are called macro-complexity and micro-complexity. Macro-complexity defines the overall information system architecture. Micro-complexity deals with components within an information system. As part of maintenance activities, it might be necessary to replace one or more components. Independent of the level of complexity, maintenance is a success only if the complexity is reduced or stays the same.

5.4 Costs

For every kind of activity related to the creation or maintenance of a software system, cost savings or avoidance are a measurable success factor. The effectiveness of maintenance can be compared with the needed resources and costs incurred from not performing maintenance. This comparison enables an organization to rate the economic justification for the maintenance efforts.

5.5 Release deadlines

Some maintenance activities must be carried out regularly, at a specific timeframe. During so-called maintenance windows, the system may be partially or completely unavailable. It needs to be clearly communicated to the users in advance when these maintenance windows take place and how long they will last. Compliance with these communicated maintenance windows is an absolute must, and it is not an option to exceed the timeframe.

5.6 User satisfaction

Measuring user satisfaction is not an easy task and usually involves a great effort of time and resources. *User satisfaction* refers to the comparison of what users expect and what the users get. The so-called gap score can be used for measuring user satisfaction. The gap score is defined by the result of the sum of deliveries minus the sum of expectations [7]. After the maintenance, the gap score must not be lower than before the maintenance. To consider the maintenance as a success, the gap score must increase.

6 WHICH FACTORS HAVE A HIGH IMPACT ON THE MAINTENANCE OF INFORMATION SYSTEMS FOR TEACHING AND LEARNING

This part of this work deals in detail with the factors that have a concrete influence on the maintenance of information systems that are operating in the context of teaching and learning. The need for maintenance of this kind of information systems can be different from the need of other information systems. The following quote defines the scope of information systems for teaching and learning. “The use of new multimedia technologies and the Internet to improve the quality of learning by facilitating access to resources and services as well as remote exchanges and collaboration” [9].

Seven key factors are identified as relevant factors for the maintenance of information systems for teaching and learning [10][11].

- Scalability
- Availability
- Data quality
- Documentation
- Accessibility
- Data security
- Robustness

The following paragraphs will explain these factors in more detail.

6.1 Scalability

Scalability is extremely important for an information system for teaching and learning. The scalability is not only related to the number of users but also to the constantly growing amount of data. Learning content grows daily, so the information system has to deal with this fact. Learning is an essential part of human life, and using information systems is therefore necessary. Through technical developments such as smartphones and laptops, it is possible to use information systems everywhere and anytime, which has also a big impact on the importance of scalability.

To ensure the scalability of an information system in the long run, perfective and preventive maintenance are necessary.

6.2 Availability

For an information system for teaching and learning, availability is connected to the user behavior more than for other information systems. The learning rhythm of the users is the key aspect for availability. Different people prefer different times of the day or different intensities of learning. Some people like learning in the morning; some like learning in the evening. Some people start learning for an exam weeks before, whereas some like to start learning days before. Regardless of these different ways of learning, it is important that the information system is accessible and working at the time a user needs it.

6.3 Data quality

Data quality is an essential aspect, as it relates directly to reliably, accuracy, and effectiveness of an information system. An information system for teaching and learning that provides wrong, inaccurate, or outdated data is useless. As a result, the learning process of the user cannot be supported; neither is it possible to do accurate evaluations about the learning process [9].

This is especially a problem for user groups such as children, because they do not yet have the ability to evaluate the truth of data [12].

6.4 Documentation

Documentation is intended to support users by providing a system for how it is supposed to be used. Children are a main user group of information systems for teaching and learning, but they often do not have the experience of using such

systems. For this reason, understandable and up-to-date user documentation is required to support the learning experience as well as possible. This documentation should be seen in the same way as software components of the system, and because of that, it also needs the same level of maintenance.

6.5 Accessibility

People with physical disabilities are also a user group of information systems for teaching and learning. Accessibility deals with, among other things, these physical disabilities and how a system needs to be developed or designed so that it is usable if a user has any physical disability. Tools such as screen-readers can help users to consume content. To make sure these tools work correctly, maintenance activities need to take place regularly.

6.6 Data security

Data security is always a valid factor for maintenance activities. Information systems for teaching and learning store and process personal data of students and also data related to assessments and exams. Data security has an essential role in this. Data breaches can have serious consequences for students and teachers and as well as the operator of the information system. Guidelines such as GDPR define some rules for information systems about processing data and how to deal with issues such as data breaches. To be compliant with such guidelines, regular adaptive maintenance is needed.

6.7 Robustness

Robustness of an information system is related to the system's ability to remain reliable and efficient, even if the system has to deal with difficult conditions. The Institute of Electrical and Electronics Engineers defines robustness as follows: "Robustness is the degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions" [13].

Among other things, the unforeseeable increases on system load as well as failures of system-critical hardware and software components are examples of such difficult conditions. In order to be able to guarantee robustness, it is necessary to understand the importance of criteria such as redundancy, fault tolerance, and scalability. Perfective maintenance is ideal to achieve robustness.

7 EVALUATION OF THE FACTORS BASED ON INTERVIEWS WITH TEACHING EXPERTS

In order to give the seven factors of the previous section more justified relevance, several experts at maintaining information system for teaching and learning were interviewed.

- **Expert A:** Employed in Educational Technology at Graz University of Technology. Tasks are the maintenance, support and management of learning and school apps, support for bachelor's and master's theses.

- **Expert B:** Media application engineer at the Salzburg University of Applied Sciences. Tasks are the maintenance and support of the internal e-learning platform.
- **Expert C:** Employed at the Educational Technology Department at Graz University of Technology. Tasks are the support of infrastructure and software development.

The experts were asked about their opinion on the factors *Scalability*, *Availability*, *Data Quality*, *Documentation*, *Accessibility*, *Data Security* and *Robustness*. The experts had to rate the relevance of these factors in terms of the maintenance of such information systems. The rating scale was defined as follows, from 1 to 5.

1. High relevance
2. Some relevance
3. Neutral
4. Little relevance
5. No relevance

Table 2 shows the result of the relevance evaluations of the interviewed experts. The influencing factors *Scalability*, *Availability*, *Data Quality*, and *Documentation* received the highest relevance ratings on average. Each of the four factors ranges between ratings of High relevance and Some relevance.

Table 2. Summary of the relevance evaluation results of the experts

	Expert A	Expert B	Expert C	Average
Scalability	2	2	1	1.66
Availability	1	1	3	1.66
Data Quality	1	3	1	1.66
Documentation	1	1	3	1.66
Accessibility	4	3	4	4
Data Security	1	2	3	2
Robustness	1	2	3	2

8 INFLUENCE OF DATA PROTECTION (GDPR) ON THE MAINTENANCE OF INFORMATION SYSTEMS WITH A FOCUS ON TEACHING AND LEARNING

Due to the guidelines of the data-protection regulation that came into force on May 25, 2018 (GDPR), it is necessary that a user consent to any data processing [14]. The consent of data processing is legal only if the person is at least sixteen years old. If a person is younger than sixteen years old, a parent or legal guardian needs to consent to the data processing of the information system. As already mentioned, one of the main user groups of this information systems consists of minors who have not reached the age of sixteen. Members of the European Union have some freedom about the age limit; they can decide on their own to lower the minimum age of consent to data processing. However, the absolute minimum age is 13 years for all members of the European Union.

Table 3 shows the minimum age of legal consent for data processing of the members of the European Union. Information systems that are already in operation need to spend some resources for adaptive maintenance so these systems can become compliant with the GDPR guidelines.

Table 3. Age at which minors can legally consent to data processing [15]

	Age 13	Age 14	Age 15	Age 16
Austria		x		
Belgium	x			
Bulgaria		x		
Croatia				x
Cyprus		x		
Czech Republic			x	
Denmark	x			
Estonia	x			
Finland	x			
France				x
Germany				x
Greece			x	
Hungary				x
Ireland	x			
Italy		x		
Latvia	x			
Lithuania				x
Luxembourg				x
Malta				x
Netherlands				x
Poland	x			
Portugal	x			
Romania				x
Slovakia				x
Spain	x			
Sweden	x			

9 CONCLUSION

This work evaluates if there is a difference between the maintenance of an information system for teaching and learning compared with other information systems.

As a result of the research, seven influencing factors for the maintenance of information systems for teaching and learning were defined.

- Scalability
- Availability
- Data quality
- Documentation
- Accessibility
- Data security
- Robustness

The factors were evaluated in terms of relevance by experts in these subjects.

Table 4 shows the results of the expert evaluations compared to the assessment of the authors. The experts as well as the authors rated the two factors *Availability* and *Data Quality* as the most relevant once. *Availability* and *Data Quality* are therefore a recommendation from the authors as influencing factors for planning maintenance activities of information systems for teaching and learning.

Table 4. Comparison of relevance evaluations of the experts and the authors of this paper

	Average of Experts' Evaluation	Authors
Scalability	1.66	2
Availability	1.66	1
Data Quality	1.66	1
Documentation	1.66	2
Accessibility	4	3
Data Security	2	1
Robustness	2	3

Also, the GDPR guidelines were evaluated for their influence on the maintenance of information systems for teaching and learning.

It can be said that the guidelines of the GDPR have no particular influence on the maintenance of information systems for teaching and learning compared with other information systems. The only difference is maybe the age of the user groups, because in the context of teaching and learning, the users are often children and students. Younger age has an impact on the amount of adaptive maintenance that may be necessary.

Finally, the question of whether there are differences in the maintenance of information systems if they are operating in the context of teaching and learning can be answered with the fact that there are definitely such differences. The factors for the maintenance of information systems for teaching and learning evaluated in Section 6 should be taken into account for planning maintenance activities, which can be confirmed by the interview results presented in Section 7.

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