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To cite this article: Muhamad Idaham Umar Ong and Mohamed Ariff Ameedeen 2020 *J. Phys.: Conf. Ser.* **1529** 052052

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A Design Theory for Student Self-service University Management System

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Abstract. The role of Information System Design Theory in software development is enormous. With the help of design theory, developers could estimate what the system will be and what the system will do. The focus of the article is to establish the design theory of a self-service university management system. The objectives of this publication are to identify the most relevant publication that will act as a guideline to generate the design theory artefacts and to establish the artefacts which will consists of three components named kernel theories, meta-requirements and meta-design for the stated system. The system scope will be focused on enabling self-service functions. Validation will be done through a traceability matrix between the meta-requirement and meta-design against the real-world user requirement. The significant of this article is to provide an initial set of design theory artefacts to be utilization software developer in development or evaluation of a University Management System.

1. Introduction

Throughout this past decade, software has become human most essential tool in getting things done. From the white-collar daily routine of self-preparation for work to top management decision-making for big corporation, software is always there to play its role. Today's software engineering challenge has also evolved. Today's software developers are challenged with task of providing the system owner with the highly desired tools. One slip up and poof, you are out of.

Software can range from something as simple as an alarm clock and complex as Enterprise Resource Plan (ERP). For a software house, the mean of survival is to be able to obtain high value project from potential clients and successfully delivering them. In relation, this action will ensure that the company will be able to gain revenue generation and to be well-known throughout the industry. In building the company's reputation and experience, more client will be looking forward to offering development work to the software house.

But in today's situation, the different software projects that are being offered through tenders are in a wide variety of requested solution with the inclusion of unprecedented terms such as big data, artificial intelligent, cloud computing, software as a service (SAAS) etc. For a software house with limited expertise and unable to cope the future request are at risk of being labelled as obsolete if there are not able to meet those technologically advance demands.

For our case, we focused on current situational problem that is faced by software houses in an open tender session. Common development team will spend less resources on User Requirement

Specification (URS) validation in the tender stage. This issue rises in the case of development project that provides this URS in the phase of competing for tender. This is due to the time and staffing constraint that are being given to the sales department and this is common for most open tender. And also, the URS itself is being present in a non-formal way with the use of natural language. Most common USR are being presented in the form of natural language such as use case descriptions, user stories, etc. [1]–[5]. In order to overcome this, the utilization of Information System Design Theory (ISDT) in evaluation of requirements is being proposed. The definition of ISDT is an initial draft of establish relationships between components of a system to achieve a specific result. Design theory must address the question of how to combine components and relationships to make subsystem and how to combine subsystems and relationships to make a system [6].

The first objective of this publication is to identify the most relevant publication that will be used a guide to the establishment of the ISDT component for the University Management System (UMS), in the context of enabling self-service functionality to the user role "Student". The second objective of this publication is to establish the three components of ISDT for the UMS which will be focusing on the stated context. The component that will be establish includes the kernel theories (KT), meta-requirements (MR) and meta-designs (MD) of the ISDT design product. Afterwards, future objective is to validate the component usability to be used in the controlled environment. The scope that the ISDT will covers is the academic aspect of the student pre-university life until the end of their study and they can be declared as alumni.

2. Related Literature

This section will describe the literatures that are related to this article. Depending on the context itself, Design Theory (DT) is being define differently by other researchers. Different type of method in the area of Design Science Research (DSR) is listed in Table 1. Design theory can be produced based on a few methods.

Table 1. Category of Theory [7]

No	Theory Category	Research Question	IS Example
1	Analysing and Describing	What is?	Taxonomy of information systems development models
2	Understanding	How and why?	Structurational model of technology
3	Predicting	What will be?	Organizational size as a predictor of innovativeness, without justification
4	Explaining and Predicting	What is, how, why and what will be	Theory of representation
5	Design and Action	How to do something?	Design of executive information systems Design of systems supporting emergent knowledge processes

Focusing more detail in the knowledge of meta-requirement for the use of developing and information system, we have established an understanding that the work of [1] in the topic of ISDT is the area of interest in our research. The next action, a systematic literature review (SLR) was conducted and the number of relevant publications that focuses on meta-requirement in the area of ISDT are listed in Table 2. The relevant publication shows that authors publication related to ISDT repeatedly show interest in establishing the meta-requirements, meta-design and kernel theories of the ISDT. Less interest is being shown for testable design product or process hypotheses. It also needs to be highlight that from the list literature, there is also exist utilization of meta-requirement and meta-design in the authors work but not in the focus of ISDT but also in the field of Action Design Research. Rather than the used of meta-design, design principles are used in publications that are related to Action Design Research.

Table 2. List of Existing Relevant Publications

No	Author(s)	Title	Year	Published in	Citation	System Scope
1	S. Sarnikar and A. Deokar [8]	Knowledge management systems for knowledge-intensive processes: Design approach and an illustrative example	2010	Proceedings of the Annual Hawaii International Conference on System Sciences	31	Project Estimation and Measurement Systems (PEMS)
2	S. Schacht and A. Mädche [9]	How to prevent reinventing the wheel? - Design principles for project knowledge management systems	2013	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	19	Project Knowledge Management Systems sub system
3	M. Dadgar and K. D. Josh [10]	ICT-enabled self-management of chronic diseases: Literature review and analysis using value-sensitive design	2015	Proceedings of the Annual Hawaii International Conference on System Sciences	6	Chronic Diseases Self-Management System
4	P. Forselius and T. Käkölä [11]	An information systems design product theory for software project estimation and measurement systems	2009	Proceedings of the 42nd Annual Hawaii International Conference on System Sciences, HICSS	5	Process-based Knowledge Management system
5	K. R. Walsh and M. H. Dickey [12]	Structured modeling group support systems: A product design theory	2004	Journal of Information and Management	5	Structured modeling group support systems
6	J. Schjerlund, M. R. P. Hansen, and J. G. Jensen [13]	Design principles for room-scale virtual reality: A design experiment in three dimensions	2018	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	3	Room-Scale Virtual Reality
7	L. De Bernardis and R. Maiolini [14]	A design theory for dynamic competencies mapping systems	2013	Designing Organizational Systems: An Interdisciplinary Discourse	2	Dynamic Competencies Mapping System
8	M. M. Herterich [15]	On the design of digitized industrial products as key resources of service platforms for industrial service innovation	2017	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	2	Industrial Service Innovation

3. Research Methodology

3.1. Information System Design Theory

The derivation of the utilization of ISDT (Figure 1) as the main DT started with the word "meta-requirement" and the sheer number of information in a URS. For software houses, the common problem of being tasked to analyze and decide whether to take part in a project tender in short period

of time. This will result in them overlooking this matter and proceed in preparing prototypes to be presented to the potential client. As other software houses, they will also have their own take of prototypes. But what makes the software houses unique. The idea of utilizing MR as a medium to analyze the overwhelming information in the URS in the form of a more "bite-size" information by connecting the URS to MR and MD of the ISDT.
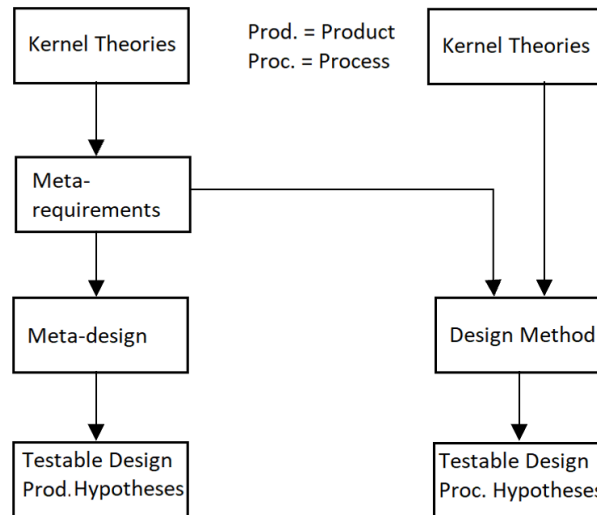

Figure 1. Component of Information System Design Theory [6]

ISDT could be another take for vendor to present their proposal by presenting an analyze that ties the URS to a DT. This will also be a novel analysis report during a proposal presentation. ISDT will give an insight of how the product could be and should be. The detail description of each of the components of ISDT is shown in Table 3.

Table 3. Description of ISDT Components [6]

No.	Component	Description
		Design Product
1	Kernel Theories	Theories from natural or social science governing design
2	Meta-requirements	Describe a class of goals which the theory applies
3	Meta-design	Describe a class of artifacts hypothesized to meet the meta-requirements
4	Testable Design Product Hypotheses	Used to test whether the meta-design satisfies the meta-requirements
		Design Process
5	Kernel Theories	Theories from natural or social science governing design process itself
6	Design Method	A description of procedure(s) for artifact construction
7	Testable Design Process Hypotheses	Used to verify whether the design method results in an artifact which is consistent with the meta-design

3.2. Focus of Product View of ISDT

The continuity of this publication is to prepare a set of suitable ISDT artefacts that will be used as a data in commencing the research scope of "abide and consistency validation of DT towards URS based on ISDT MR and MD artefacts". The initial stage is to set up a controlled experiment for ISDT MR and MD, a based data will be setup. Current available input that is being use for our research is a set of UMS URS. Formulation of UMS ISDT that will be used together with UMS URS. Next publication will be focused on a traceability matrix of UMS URS and ISDT MR and MD.

3.3. Selecting Kernel Theory

A few potential publications that is consistent with the scope of this research where the (1) ISDT artefacts are in natural language and (2) traceability between MR and MD are being define by their respective author. Table 2 listed the details of the existing publication that will serve as guideline and kernel theory to our research MR and MD formulation. Further inspection and review of each publication, it is decided that the works of S. Sarnikar and A. Deokar [2], M. Dadgar and K. D. Josh [4] and L. De Bernardis and R. Maiolini [8] with attention of extra effort of L. De Bernardis and R. Maiolini [8] are the most relevant. A definition of a complete ISDT artefacts must include all ISDT aspect of the product design theory which must include kernel theories, meta-requirements, meta-design and testable product design hypotheses.

Kernel theory refers to theories from natural or social sciences governing design requirements [1]. It could be an academic theory or a practitioner theory-in-use. Kernel theory enables formulation of empirically testable predictions relating the design theory to outcomes like system requirement fit. Developing an ISDT for stated context requires a kernel theory to provide a basis for dealing with system development.

The focus of UMS develop is focusing on allowing self-service functionality towards users, with consideration student and academician related functionality as the highest priority for the system. Kernel theory that is being utilized for this research will be based on a SLR that was conducted in order to identify similar past publication that is suitable and is adopted for the use of our research, plus the use of Student Handbook and interview session with multiple domain experts. The Student Handbook is a crucial information for the use of student that contains in details all the rules and regulations that must be abide. In the student handbook, some of the relevant information which are align with the design theory of UMS are as follows:

- Academic calendar
- Programme registration
- Course registration
- Credit scheme
- Credit exemption
- Grading scheme
- Assessment
- Academic status
- Academic award for diploma and degree
- Study Deferment
- Change of programme

The scope of publication, preparation of experimental data and does not focus in improving the field of ISDT what so ever. The define kernel theories plus an analysis of existing ISDT artefacts based on previous researches should be adequate for the formulation of MR and MD. Generated artefacts are up to standard aligned with previous publication, plus MR and MD should be traceable to their respective artefacts. With the modification to the MR and MD of the existing publications and making sure it is in line with the nature of student self-service in UMS, this will be used as the main artefacts of the ISDT.

3.4. UMS Meta-requirement

This section presents the MRs for the design product theory for the class of UMS, which was based on the define kernel theories (refer to 3.3). Based on the student handbook and existing relevant publication in the area of ISDT, we are able to formulate a set of meta-requirements that describe the UMS in the focused context and will satisfy the defined kernel theories. Meta-requirements are defined to suit the need of the students, but at the same time enabling other users such as academician to provide meaningful input towards the system. This set could be utilized in different ways depending

on reader attention, but not limited to development and evaluation of future or existing system with the same theme. Table 4 details the meta-requirements for an UMS system.

Table 4. List of UMS Student Self-service Meta-requirements

No.	Meta-requirement	Unique identifier
1	To provide highly accessible and round the clock self-directed with authorization control and policies	MR1
2	To enable user empowerment through self-management	MR2
3	To support critical time-based events related to academic calendar	MR3
4	To facilitate better self-awareness and self-accountability of student performance	MR4
5	To provide feedback on student's achievement or penalties	MR5
6	To support interpretation of single or multitude number of student's performance in pre and post-mortem analysis	MR6
7	To maintain high level of informational authenticity and integrity	MR7
8	To manage inter-dependencies between student and staff	MR8
9	To support aligning the basis of university structural establishment and its evolution	MR9
10	To provide feedback on highly challenged student per case based	MR10
11	To support work-around in handling academic related issues	MR11

3.5. UMS Meta-Design
This section outlines a generic MD for the class of UMS based on the define kernel theories and meta-requirements. The formulated MDs are used to satisfy the stated MRs in Table 4. In order to achieve this, a column state the relation of each meta-design to their respective meta-requirements is also included in Table 5.

Table 5. List of UMS Student Self-service Meta-design

No.	Meta-design	Unique Identifier	MR Traceability
1	Multilinguals, personalized interfaces, features for information exchange, dynamic adaptation of contents to user profiles, policies and modules for managing authorizations, authentication module and rules for authentication	MD1	MR1, MR2, MR3
2	Easy-to-use, creative, connected, integrative, participatory and inclusive	MD2	MR2, MR3, MR4, MR7, MR9, MR11
3	Multidimensional dashboard and report generation	MD3	
4	Capture multimedia information and basic student and university information	MD4	MR5, MR6, MR7
5	Real-time and batch update of information	MD5	MR5, MR6, MR7, MR8
6	Individual student study performance monitoring	MD6	MR5, MR6, MR10
7	Facilitative input of information setup that will enable "Just-in-time" functionality	MD7	MR8, MR10

4. Validating Meta-requirement and Meta-design by Traceability Matrix
In order to ensure the authenticity of the formulated DT, a traceability matrix will be referred to trace the horizontal and vertical consistency of each MR to their respective user requirements (UR). This UR will be based on the URS document of the UMS. The traceability matrix will enable assessment from two different aspect of the MR and MD towards the UR. (1) Horizontal Consistency. This matter

will ensure that the MR and MD formulated in the article is able to be trace back to their original requirement. And (2) Vertical Consistency. With the completion of the mapping of MR and MD to their UR based on correctness, it will also show whether the correctness aspect of the mapping is consistency with the MR traceability that is shown in Table 5. If there are some mismatch shown in this evaluation, then further calibration of MR and MD is needed to ensure they are correct and also consistent. Future publication will address the content of this chapter in more detail.

5. Conclusion and Future Works

This publication main objective is presented based on the UMS design theory. The main contribution of this publication is (1) presenting the most relevant publication that is served as the main guideline of this research and (2) presenting the set of meta-requirements and a meta-design of a UMS, focusing on self-service enabling for students. It is an earliest indication of what an UMS could be, with the utilization of ISDT focusing on the aspect of enabling self-service. With this, it could help software houses to propose, implement or evaluate a management system for a university. Software houses could use the theory (1) to ensure the critical needs are established, (2) to evaluate on the correctness and consistency of future similar theme projects.

Limitation of this publication is the artefacts are does not represent the UMS as a whole, but only focused on the part of student's need of a self-service system and also the other parties that will impacted and impacting the different outcome of the student's study life. Also, the publication does not cover the Testable Design Product Hypotheses and the process component of the ISDT (Design Method and Testable Design Process Hypotheses).

Future research will be to calibrate the established artefacts by performing a consistency analysis by referring to the real-requirement and to tie together these artefacts with them based on the method of Machine Learning in Natural Language Processing (NLP). Further improvement to the artefacts is foreseen and a new article will be published as a revision to the artefacts presented in this article.

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