Tasks, Processes, and Tools: A Design Methodology Management Approach to Design and Development of E-Assessment

T. Dube*, M. Ma** and Z. Zhao***
* University of Derby/School of Computing/Derby, United Kingdom
** Glasgow School of Art / Digital Design Studio/Glasgow, United Kingdom
***Shijiazhuang Tiedao University/Faculty of Information Science and Technology/Heibe, China
t.dube@derby.ac.uk; m.ma@gsa.ac.uk; zhaozx@stdu.edu.cn

***Abstract*— As technological approaches continue to dominate provision of education in this modern age, effective methods and techniques should be employed in the development of the supporting systems. In this paper we discuss the use of Design Methodology Management (DMM) technology in the development of a formative e-assessment system to support the learning process. DMM promotes a framework type modular approach to system development thereby promoting flexibility and extensibility of the system. Most existing applications of design methodology management, particularly in the electrical design field, have focused on automation of the design process. Our main focus is on the structural representation of the system as well as the flow of data between its components. We first discuss design of the generic e-assessment framework and then describe how we used it in the context of a Data Analysis formative assessment.**

I. INTRODUCTION

A. Definitions

The three distinct key words in *Design Methodology Management* are worth defining first for better comprehension of its meaning.

Design - Reference [1] defines 'design' as firstly, a plan to bring about a man-made product, with that plan aiming to achieve a prescribed goal and satisfy certain constraints; secondly, it is seen as a process of the creative development of such a plan. It can also be defined as a plan for a program to solve a particular problem reflecting the broad structure or architecture of the program. This includes the way it will be broken down into components such as procedures, functions, and data structures as well as an overview of the interrelationships between them. Design creates a representation or model of the system as argued in [2].

Methodology – Methodology is defined as a sequenced set of operations employed in performing a particular function such that, given a methodology, the function can be performed in a predictable and repeatable way [3]. Reference [4] defines design methodology as "the processes, techniques, or approaches employed in the solution of a problem or in doing something: a particular procedure or set of procedures". Reference [5] sees design methodology as sequence of activities required to get from one stage of the design process to another and summarizes it as Design Methodology = Tool set + Design Flow + Constraints. Reference [6] views design methodology as a hybrid design method that uses the techniques of data analysis, structured analysis and top-down design among others. He describes the underlying design methodology system model as consisting of data stores, data flows and processes as well as users. Fig 1 is a representation of this model.

Management - Reference [7] defines methodology management as the functionality of selecting and executing design tools. It is also viewed as the management of a design methodology's component parts, i.e. management of the toolset, the design flow and any required constraints [5]. It addresses the need to manage the manner in which design tools are executed to achieve a desired function.

Design Methodology Management deals with the execution and control of the tools and tasks used in the design process. Reference [8] defines design methodology management as "the selection and execution of an appropriate sequence of tools to produce a design description from available specifications." The main goal of design methodology management is improved productivity on the part of designers making their jobs quick, easy and less error prone. Three attributes of an ideal methodology management system are: 'maintainable', 'parallel', and 'flexible'. If the system is maintainable, adding new tools and supporting new methodologies becomes a straight-forward process. Parallelism relates to the possibility of executing independent tasks at the same time. The system can provide the user with the flexibility of either selecting and executing tools automatically or providing the user with enough information about the tools so that they can manually select as appropriate.

B. Background

Design Methodology Management spawned some

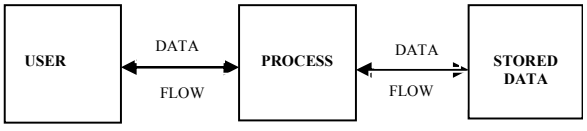

Figure 1. Design Methodology System

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research in the 1980s, but there was even more research activity in the 1990s as evidenced by the various research deliverables in the form of conference and journal papers, and also theses within that decade (e.g. [1], [4], [5], etc.) The origins of DMM are linked to electrical Computer Aided Design (CAD) frameworks. CAD frameworks can be generally described as software environments which provide data management, design flow management, a tool interface, and a user interface. Data management deals with efficient storage (in a database) and retrieval of the design data. Design flow management is about automatic selection and execution of tools used in the design process which promotes rapid production of designs. The tool interface is used for scheduling, integration and execution of tools whereas the user interface is for interaction between the designer and the framework. Examples of CAD frameworks include NELSIS which emphasizes data management, and ULYSSES which focuses on tool management. The following statement sums up the link between CAD frameworks and DMM: "design methodology management systems may be regarded as 'one of the fruits of a good CAD framework'" [4]. An in-depth review of DMM systems as well as concepts is presented in [4].

Design methodology management has been a topic of discussion mainly in the field of Electrical Computer Aided Design (CAD) but it is also applicable to other fields of design like mechanical, manufacturing and software. Different developers and researchers have focused on different aspects of DMM. Some concentrated on design flow management while others were interested in task management, etc. Our work falls under the software design field and the main focus is on modeling of the system using design methodology management concepts to give a clear overview of the system including the flow of data within it.

C. *Design Methodology Management Concepts*

The key concepts which also form the requirements of a design methodology management system are: *tool, process, task,* and also *execution and control.*

A tool is defined as a single executable program capable of performing a specific design function. Tools are required to be described and executed in a manner that is generic and extensible regardless of being automatic or interactive.

A process is a combination of tools and/or other processes that perform a design function. This entails flow of data.

A task is described as an abstraction of a design function. Description of tasks must support sequencing of tools to be executed within the task as well as intra- and inter-task dependency definitions like output and input relations. The descriptions should also include flow control constructs such as conditional branching, selection and iteration, and portability to different design environments.

Execution and control plays the management role of a design methodology management system allowing users to invoke tasks and tools and to monitor their states. The execution environment provides the processing context for tool integration and task flow models. Fig 2 summarizes these descriptions and it forms a basic design methodology management framework on which development of our e-assessment system is based.

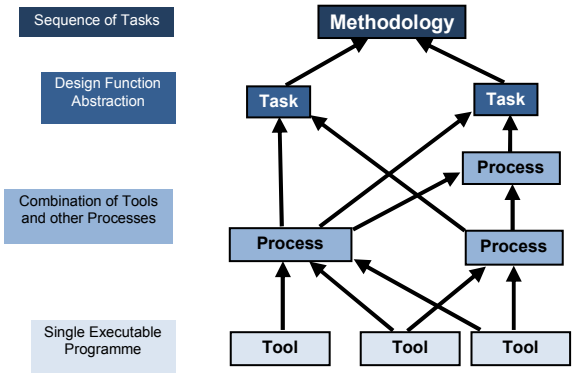

Figure 2. Design Methodology System

II. Overview of E-Assessment Processes

E-assessment is one of the domains of e-learning which involves the use of technology in its provision. Our working definition is given by the Joint Information Systems Committee (JISC) as, "the end-to-end assessment processes where Information and Communication Technology (ICT) is used for the presentation of assessment activity and the recording of responses" [9].

The major benefit of e-assessment systems is their flexibility in terms of global access or anytime, anywhere access. This is made possible by the use of the Internet.

The following is an outline of the general procedures involved in taking an e-assessment.

1. **Access** – The user opens the system by double-clicking on the system icon on their computer desktop or by clicking a web link.
2. **Authentication** – The user logs in, or registers their identification details, for security reasons and also for mapping the feedback to the correct user in a personalized way.
3. **Presentation of assessment activity** – The assessment material is now presented to the user, mainly the questions but also the instructions on the computer screen.
4. **Answering the questions** – The user answers the presented questions which may be all or more than one on a screen or page, or one at a time.
5. **Recording of responses** – The system records all the user's responses or answers to the questions.
6. **Marking the responses** – The system automatically marks the user's responses to the questions.
7. **Presentation of feedback** – The system displays the feedback which can be in form of marks gained or indications of the correct responses, etc, following the marking.

Various other processes, algorithms and settings are undertaken in the background in order to accomplish the above procedure. For example, users' identification details need to be stored somewhere, e.g. a database or a file so that the system can check the entered information at login to see if it matches the stored data. The same applies to the recording of results stage as well as the marking stage. Details of these underlying processes are described in the actual system development. Table 1

TABLE I.
E-ASSESSMENT SYSTEM AND USER RESPONSIBILITIES

Stage	User	System
Access	- Double click system icon, or - Click on web link	- Show interface on computer screen
Authentication	- Register identification details, or - Login	- Record user identification details, or - Check user identification details
Presentation of assessment activity	- Read instructions - Read questions	- Display instructions, and - Display questions on the computer screen
Answering questions	- Give response / answer to question	- Show means to answer the questions, e.g. text entry box
Recording of responses	- Submit given answer	- Store user's response
Marking of responses		- Apply marking algorithms - Allocate mark
Presentation of feedback	- View or read the feedback on the computer screen	- Display feedback on the computer screen – show attained marks; indicate correct answer

shows the responsibilities of the user and the system in following the outlined procedure.

III. MAPPING E-ASSESSMENT PROCESSES TO DESIGN METHODOLOGY MANAGEMENT MODEL

From the definition of e-assessment given in section II of this paper as well as from the information presented in Table 1, we identify the e-assessment tasks to be presented at the top level of the design methodology management model as presented in Fig 2. The top-down design approach is therefore employed to begin with.

Tasks

The main tasks are:

- Presentation of assessment activity
- Recording of responses
- Marking
- Presentation of feedback

The sequencing of these tasks forms an e-assessment design methodology. This can be diagrammatically represented as in Fig 3 showing the view of design methodology as activities to get from one stage of the design process to another. That way the first stage and the last stage (the beginning and the end) can easily be identified. So in our formative e-assessment system case, the first major activity (task) is *presentation of assessment activity* and the last one is *presentation of feedback.* These two tasks form the core purpose-oriented objectives of the system, providing a means for students to engage with learning material.

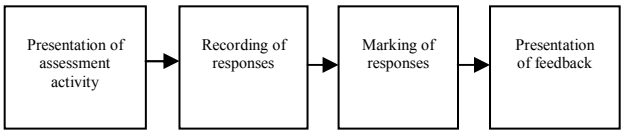

Figure 3. E-Assessment Design Methodology

Another important task which has not been explicitly mentioned before is *Management of user* activity which is applicable at various stages of the design methodology. It includes storage of user identification details needed at the authentication stage, recording of user responses, etc. In Fig 4, the place of this task is shown. Dashed arrows have been used to show the relationships between the main tasks and the implied management of user activity task.

A double-headed arrow has been used between *Presentation of assessment activity* task and the *Management of user activity* task to represent the fact that data related to management of user activity can flow either way from and to these tasks. In the first instance, following Table 1, the user has to either register their identification details or login using the previously registered details. The system manages this process by recording the user's details in a database. If the user enters login details like identification number, the system checks if the user has been registered before and if so, it compares the login details with the information registered about them. Once the authentication stage is passed, the assessment activity is now displayed on the computer screen for the user to tackle. During this presentation of the assessment activity stage, the user may decide to log out of the system at any point. They would be able to do that by clicking a 'logout' button on the computer screen. The system manages that by recording that the user in question has logged out of the system. This accounts for the second arrow head from the *Presentation of assessment activity* task to the *Management of user activity* task.

The arrow from the *Recording of responses* task represents the system's responsibility to store the user's submitted answers to the questions in the assessment activity. The responses are stored in such a way that they are linked to the user's identification details. That way, at the end of the assessment activity, the system will display relevant feedback to each user. The double-headed arrow between *Marking of responses* task and the *Management of user activity* task denotes that firstly, the system requires the user's stored responses in order to mark them. Secondly, following the marking, marks or results are stored in a database to be displayed at the last stage as feedback as depicted by the arrow head from the *Management of user activity* task to the *Presentation of feedback* task. The arrow head at the other end represents the notion that a user may log out of the system after viewing the feedback and, as previously stated, the system will need to record that status.

In DMM terms, the arrows, whether unidirectional or bi-directional represent the *design flow* which effectively is the flow of data.

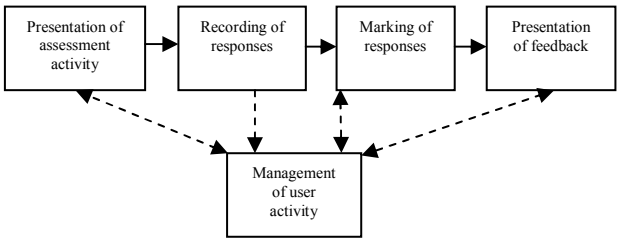

Figure 4. E-Assessment Design Methodology with Management Task

Processes

Below the task level are the underlying processes that are carried out in order to perform the defined tasks which are abstractions of the design functions. Each of the tasks has specific processes that help accomplish it though some processes may be relevant to more than one task especially considering the purpose of the *Management of user activity*.

- *Presentation of assessment activity processes*

The assessment activity is presented by way of displaying it on the computer screen as presented in Table 1. This includes the instructions as well as the questions. So we identify *displaying instructions and questions* as one of the processes needed to achieve this task. This data (instructions and questions) should be stored somewhere to be displayed. As such, *data management* is another process which deals with storage, selection and retrieval of the assessment activity. During presentation of the activity, users should be able to move from one question to the next or back to the previous. This incorporates the *navigation through the assessment* process.

- *Recording of responses processes*

Storing of student answers is the eminent process of the task of recording of responses. Underlying processes include *identifying given answer* which is important for correct recording or storage of the answer. This links with the stage of 'Answering questions' which is sandwiched between the 'Presentation of assessment activity' stage and the 'Recording of responses' stage as presented in Table 1.

- *Marking processes*

Marking processes include *applying marking algorithms* which involve *comparing given answer and correct answer, and allocating marks* per question. The process of applying marking algorithms may be associated with the different question types which include: multiple choice questions (MCQ), true/false questions, gap-filling questions, graph-plotting questions, matching questions and free-text response questions.

- *Presentation of feedback processes*

The main process to achieve presentation of feedback is *displaying score or grade.* For formative assessments though, *displaying correct answer* may be considered the main process as it is required to promote learning. Depending on the purpose and/or requirements of an assessment, the correct answer may be displayed immediately after a student submits an answer. Alternatively, the feedback for all the questions may be displayed at the end of the assessment activity with the given answers displayed alongside for comparison.

- *Management of user activity processes*

One of the main processes of the 'Management of user activity' task is *user account management*. This includes storage of user identification details during registration, and also verification of identification information entered at login. This process is important as it unlocks the system for the user since the assessment activity can only be released when the user has been registered or when their identification information has been confirmed. For assessments which do not need to record student details, this process may be omitted. Due to the centrality of the role played by the 'Management of user activity' task in relation to other tasks as demonstrated in Fig 4, other processes which fall under it are, *storing students answers, comparing given answer and correct answer, selecting correct answer* and *displaying score or grade.*

The generic processes level of the mapped DMM model is shown in Fig 5.

Tools

To complete the DMM framework for e-assessments, we now define the tools required to fulfill the established processes. Considering Fig 5, from left to right, we first define the tools required for the 'Presentation of assessment activity processes'.

- *Tools for Presentation of assessment activity processes*

As previously discussed, for the questions and instructions to be displayed, they should be stored somewhere like a database or a file which needs to be created or set up and managed. This entails such tools as: *create, save, delete, add, update, edit, select, and open.* These tools deal with handling of data. For the process of navigating through the assessment, tools required are for moving forwards and backwards and we define them as, *next* and *previous. Login, logout* or *exit,* are also form of navigation tools. Users may be redirected to other web pages or other applications via links from the displayed assessment activity pages. This requires a *redirect* tool. If a user is automatically presented with the next question after they submit an answer, *submit* can be added to the tools for navigation.

- *Tools for Recording of responses processes*

The recording of responses happens when the students submit their answers. We therefore identify *submit* as the fundamental tool for the process of storing students' responses. Storing the responses to a database or file that is already created means that the responses or answers are added to already existing data so, *add* or *insert* tool is needed. Also, since the students can navigate through the assessment backwards or forwards, they may decide to change their previously recorded answers and this requires an *update* tool.

- *Tools for Marking processes*

Marking processes call for a tool to compare given answer and correct answer. We call the tool *pattern matching.* Allocation of marks is carried out following the execution of the *pattern matching* tool. Therefore, the tool is self-contained to serve the marking processes.

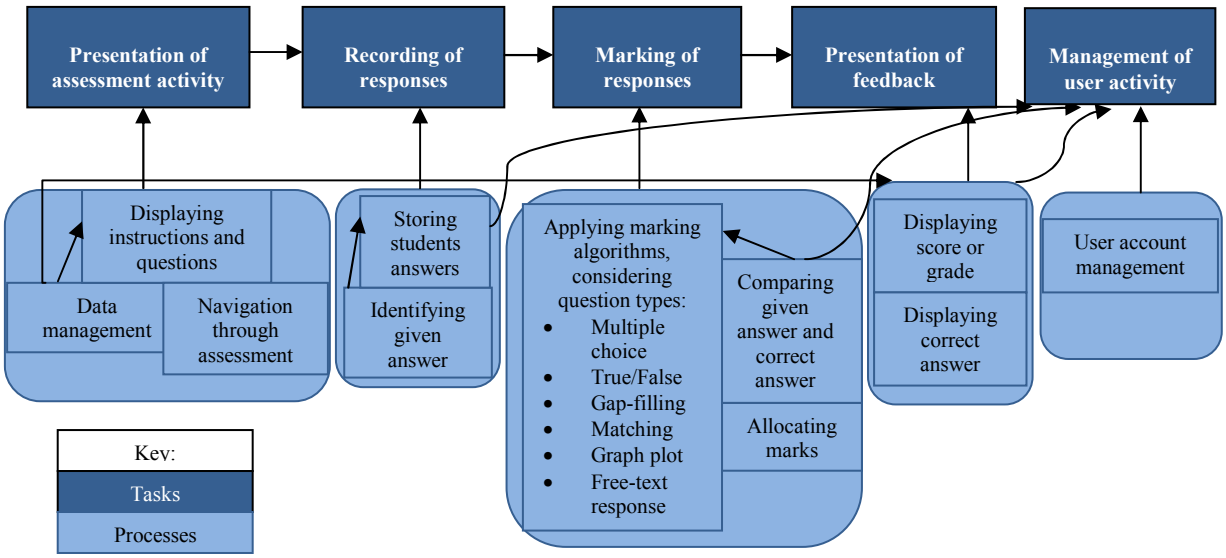

Figure 5. Processes in E-Assessment DMM model

- *Tools for Presentation of feedback processes*

The marks allocated to the student's answers during the marking processes should be calculated before the grade or the score can be displayed. This brings about the *calculate marks* tool. The resulting calculations can be displayed as percentage or as grades. Correct answers need to be selected from the database or file so that they can be displayed, and to achieve that, a *select* tool is defined.

- *Tools for Managing user activity processes*

To manage a user's account, tools needed are: *create account, create password* and *update password.* The involvement of the 'Management of user activity processes' with processes of other tasks which include, storing students answers, comparing given answer and correct answer, selecting correct answer and displaying score or grade, means that some of the tools associated with those processes are also relevant to it. These include, *submit, add, update and select.*

IV. IMPLEMENTATION

A. Requirements of a formative e-assessment system

For the purpose of our study, we used requirements for a formative e-assessment system to support the learning of Data Analysis techniques. A formative assessment gives students an opportunity to engage with learning material and it can be used to help them prepare for summative assessment which is given at the end of a study period normally contributing to their final grade.

The stakeholder, a lecturer of Data Analysis at the University of Derby, required an e-assessment system which could support first year students' learning of data analysis techniques using excel spreadsheet. The lecturer realized how students use manual methods to make various calculations instead of using Microsoft excel's built-in tools to achieve the same results quickly and probably easily.

Nine different variables were given in a table with varying data for 'mean, median, standard deviation, coefficient of variation, skewness measure, range, minimum value, maximum value and number of values'. The students were to use the data to answer questions on the different data analysis aspects by identifying the correct data values from the table and also performing calculations on the data. One of the key requirements was for the data variables to be randomized so as to enable the students to practice on different types of data each time they accessed the assessment. This has implications on the storage of the data.

B. System Architecture

We used the designed e-assessment DMM model as well as the client requirements as guide in the development of the system, starting with its architecture as represented in Fig 6. Central to the system is the database which aids management of the assessment data and the flow of data through the system. The database is storage for the following data segments: questions, answers to questions (for marking purposes), question types, mark value of questions; data variables; students' identification details, including first name, family name and student number; answers given by the students, marks allocated per question per student as well as grades and scores. MySQL database which was already available was used while being hosted by a secure Linux server which also contains the rest of the system files.

The students interact with the system via a web browser on their computers or other devices which connect to the internet. So the other key feature of the system is the *display unit* which can be a computer monitor or a mobile device screen. This is where the registration or login form is displayed for students to fill in order to access the system. As noted in Table 1, students access the system by clicking on a web link to the assessment hosted on the server. The system displays the assessment activity onto the display unit where the students also input their responses to the assessment questions. Once marking is done, the students can also view their feedback on the display unit.

The system files and resources package on the server is a vital component which supports the running of the of the e-assessment system. The files contain definitions of the various tools and processes as well as the flow of data

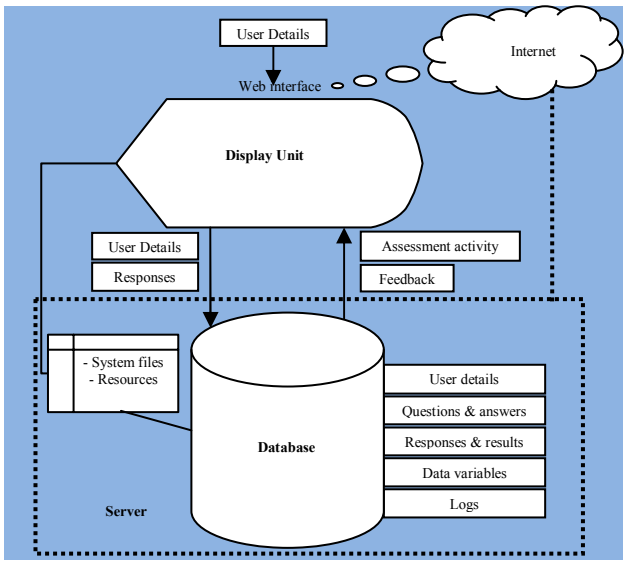

Figure 6. E-assessment System Architecture

as code statements and functions towards fulfillment of the system tasks. The definitions therefore include connections between the display unit and the database where major system activity occurs. Marking algorithms, style sheets and configuration details are also defined in the files. We used PHP scripting language, which suits web application developments, to develop the formative e-assessment system.

C. System Evaluation

Following completion of the development of the system, the Data Analysis students were given the web link to access the assessment. The database was designed in such a way as to track students' activities or interactions with the system. The entries reveal that more than 100 students at least registered their identification details in the system's database. There were about 120 results indicating that students participated in the assessment activity. Out of the 120 results, some are for the same students who engaged with the learning material and practicing answering the data analysis questions using the different data variables which were randomized. This high level of interaction with the system is an indication of students' satisfaction with it. So basically, the system successfully served its purpose. From the few survey results we got, students found the system easy to use and flexible as some accessed it from home while others within the university. Because of the structural flexibility of the system enabled by design methodology management technology, in response to the students and lecturer's feedback, we were able to add more tools for added processes like navigation through the system using 'next' and 'previous' buttons. Text entry marking was found not to be very accurate so it's an area of further research.

V. CONCLUSIONS

In this paper we have defined design methodology management technology identifying the key words that make it up: *design, methodology and management*. While its background shows much activity of application in the electrical computer aided design field, the concepts of design methodology management are applicable to other fields as well. We have demonstrated a different approach to the application of design methodology management as well as to software design. The key concepts of design methodology management, viz: task, process and tool, indeed promote some flexibility in the design of systems. For example, depending on the requirements of an e-assessment system, other tools and processes can be added to the constructed framework in order to tailor it as appropriate.

The structural representation also acts as valuable documentation for the system. That way, another developer could add other entities and extend the system. In our next publication, we aim to present other case studies of adoption of the established Design Methodology Management Framework for E-Assessment Systems to describe the various experiences due to different requirements by the stakeholders.

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