Design and delivery of an E-assessment solution at the University of Duisburg-Essen

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1.   EXECUTIVE SUMMARY

Recent reports by the European Commission highlight the necessity for e-assessment solutions with a focus on standardization and budgetary aspects of assessment-related processes, which directly affects all universities (Scheuermann, Pereira 2008). The potential advantages of e-assessment solutions (as compared to non-digital assessment solutions) can be subsumed to the following time and cost efficiency factors: Authoring of exams, Supervision, Evaluation, Grading, and Grade transmission to the administration office.

1.1. Background

In the next five years, the German education system is subject to two major changes: a) the introduction of new bachelor and master degrees in higher education and b) the decrease of the average duration for pre-college education leading to a degree that allows access to higher education, from 13 to 12 years.

Although both steps represent strong efforts in moving closer to a European standardization in education, they result in – among other things – a higher amount of assessments, especially with regard to examinations.

As one of the ten largest universities in terms of enrolled students, the University of Duisburg-Essen (UDE) tries to master this challenge by introducing an e-assessment solution for its 30.000 enrolled students and its 470 professors. The primary objective is the delivery of an IT-supported system that supports academic staff in a faster and more efficient assessment process.

1.2. Alternatives

There are numerous examples of European universities that have started e-assessment projects, including the University of Bremen (2009), the Freie Universität Berlin (2009), and the University of Münster (2009). With a focus on large groups of participants, Bücking et al. have published a comprehensive report (Bücking et al. 2007).

1.3. Conclusions

This paper describes the design considerations, the software selection process, and the delivery strategy of a computer-based assessment system at the UDE. Following a process-based approach, the platform was implemented with LPLUS.

2.   PROCESS-BASED APPROACH

First, the underlying business processes were identified based on the existing assessment situation. Thereafter, the process chain was modelled (as visualized in Figure 1).

Figure 1: Assessment process chain

One of the projects important constraints was to provide a solution presented for multiple-choice exam scenarios in ECTS-generating courses for large groups of participants (that is, more than 120 students).In particular, the processes authoring, supervision, evaluation, grading and grade transmission have been scrutinized with regard to their time and cost efficiency.

The authoring of a "good" exam is still subject to discussions within the pedagogy community. It is not discussed in this paper. Nonetheless, the creative aspect is definitely a human-centred task. Yet, it can be supported by intuitive authoring tools.

The publication of an exam in paper form is usually carried out by a printing centre at known costs. However, costs may increase if different masters are required. For example, if prints with different permutations of questions or if different subsets of exam questions are required. We want to call this additional requirement the "permutation requirement".

In exam scenarios, the authorization of a person to participate in an exam is achieved by a list of participants' names and study id numbers. The identity is then proven by official documents (id, study card, social insurance card, driving license). Using IT-based technologies for this process are fairly expensive and would require the availability of biometric data. Therefore, the supporting process of identification and authorization of an exam participant is considered a human task.

The delivery process describes the distribution of the exam for interaction with the participant. In "pen and paper" scenarios, staff will handout exams. In IT-based scenarios, this is the central process, which results in an interactive (and individual) exam appearing on each pc screen. We will discuss the delivery strategy later in detail.

Supervision cannot be completely replaced by machinery. However, random-based exercise selection algorithms make cheating attempts more difficult and non-deterministic and overcome the necessity to develop and print multiple versions of an exam. Although they are not applicable for all kinds of learning evaluations, multiple-choice questions represent a very common methodology for the measurement of learning activities. Since the multiple-choice approach can easily be implemented and evaluated in computer-based scenarios, it is the preferred methodology with regard to time effectiveness. Again, grading is a process that should remain in the responsibility of the educator. IT can support with visualization and calculation tools. The transmission process of final grades to the administration office can be supported by preventing media discontinuities like manual transcription of grades from paper list to spreadsheet application or vice versa.

Evaluation and grading occur in the faculty. In some cases, written exams are opened for inspection by participants.

Finally, the grades are transmitted to the university administration where they are filed or stored in an administrative database.

3.   DESIGN REQUIREMENTS

After modelling the process chain, special additional requirements were collected and defined.

It was stated, that the identification, authorization and supervision of students should occur in a face-to-face situation, the exams are to be taken a) in a central room and b) on-campus. Supervision staff in one or more rooms assures that exams are taken by the correct person and without any other knowledge sources than the ones allowed.

In addition to the identified time and cost factors, the following university-specific requirements were given.

- Alternative usage scenario "Pen & paper": Due to a shortage of room capacities for large groups of students, the implementation should also allow classical "pen & paper" exams.

- Alternative usage scenario "PC-Hall": The resources at hand should be used as an ordinary student PC hall during off-exam situations.

- Time and cost savings are more significant for large groups. The room should provide exam places for at least 120 or more students.

- Precaution measures for the prevention of unwanted or deliberate failure of equipment that results in a student's inability to participate in an exam.

- Anti-theft measures for the IT equipment: A large PC hall contains hardware with a high value.

- Legal certainty: When answering questions to a machine, all exam-related interactions on the man-machine interface must be logged in order to obtain legal certainty.

- Anti-cheating measures: The larger a group, the more supervision staff is needed. Although visual barriers hinder students from copying someone else's answers or from communicating with each other, they also hinder supervision staff from registering inappropriate cheating attempts. Instead software-based methods like exercise permutation is a more promising approach, especially for the dual-use scenario (e-assessment/pen&paper)

- Usability of on-site equipment: The on-site equipment has to meet the demands of the three use cases e-assessment, "pen & paper" and "PC hall" with regard to ergonomics, furniture and IT.

- Usability of authoring tool (software): E-assessment requires an existing pool of exercises. Hence, authoring is the first crucial step and the authoring tool must be accepted by the authors.

- Digitalization of business process: The e-assessment system must be integrated in the existing digital business processes at the University of Duisburg-Essen, i.e. the system must feature a data import filter for the HIS/QISPOS compatible Excel table format for the lists of participants and the corresponding data export filter for the results.

4. DESIGN DECISIONS

Several platforms have been evaluated, including Moodle, QuestionMark, EXPLA, and LPLUS. The two "must-have" criteria were legal certainty and the availability of a high service quality level.

Due to its superior references (including the European Aviation Safety Agency, the Swiss *Bundesamt für Zivilluftfahrt*, and the *Luftfahrtbundesamt* in Braunschweig, Germany), its features, its support delivery quality, and its cost-benefit ratio, the University of Duisburg-Essen has acquired the LPLUS software suite as its e-assessment platform (2009).

In comparison with other e-assessment platforms, LPLUS has the most advanced data integrity and user interaction logging strategy in order to provide legal certainty. The correctness of the LPLUS software and the legitimacy of its functionalities have been positively confirmed in various national and international judgements that resulted from law suits against e-assessment providers using LPLUS. In addition, the software house is located at near distance (in Germany), has appointed a key account manager for the UDE and has a highly qualified support hotline. The authoring tool is very intuitive and features support for multiple-choice questions as well as for interactive "drag & drop" question scenarios.

5. DELIVERY STRATEGY

The delivery strategy fulfils special requirements including a multiple usage scenario as a pc hall, as an e-assessment room and as a "pen & paper" exam room. Furniture and multimedia equipment were chosen with the primary objective to prevent unwanted or deliberate failure of equipment that could potentially result in a student's inability to participate in an exam.

5.1. Room layout

The tailored combination of room lighting and multi-purpose desks with bottom-mounted TFT monitors and concealable keyboards also meets ergonomic demands. A large room is currently renovated as a pc hall for 196 users (that is, a group of 178 users + 10% compensatory seats for an e-
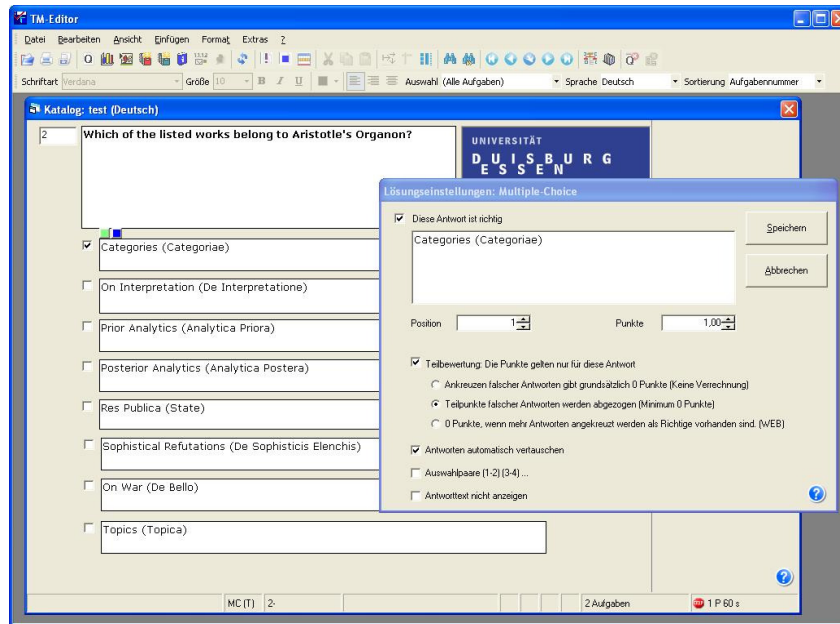
assessment situation). Compensatory seats are used if PC clients are malfunctioning in an e-assessment scenario. The maximum endpoint system failure rate is expected to be 10% at most. This means that a simultaneous failure of 18 PCs can still be compensated. In the meantime, the system is already used in small pc halls with 40-50 seats. The servers will be kept in a separate server room. The room layout is given in Figure 2.

Figure 2: Room layout

5.2. Database

In IT-supported assessment systems, all exam-related interactions on the person-machine interface must be logged in order to obtain legal certainty. In addition, the system was implemented to meet high availability and data integrity demands. The database runs on MS SQL Server and is mirrored asynchronously. Backups are run on a daily basis and are stored remotely via an IBM Tivoli Storage Manager system (TSM).

5.3. Authoring

The authoring tool is distributed via the CIM intranet web page under a campus-wide license for all UDE members. The application runs on MS Windows platforms. The result of an authoring session is a question catalogue that can be uploaded to the LPLUS database. Authoring courses are organized by the CIM and on-demand on a regular basis. Since the creation of a question pool is an obligatory prerequisite to an e-assessment system, the promotion of e-competence with regard to the authoring tool is a high priority task in the roll-out strategy. Despite the resources for establishing the authoring tool among the potential authors, the acceptance of the tool also depends on its usability. Judging from the user's positive feedback and the short time period between the first courses for authors and the first e-assessments carried out, it can be stated that the LPLUS authoring client is a user-friendly application.

The supported question types include various Multi-Choice (MC) types, open questions, image and video support, as well as complex interactive drag & drop questions. Authoring examples are depicted in the Figures 3 and 4.

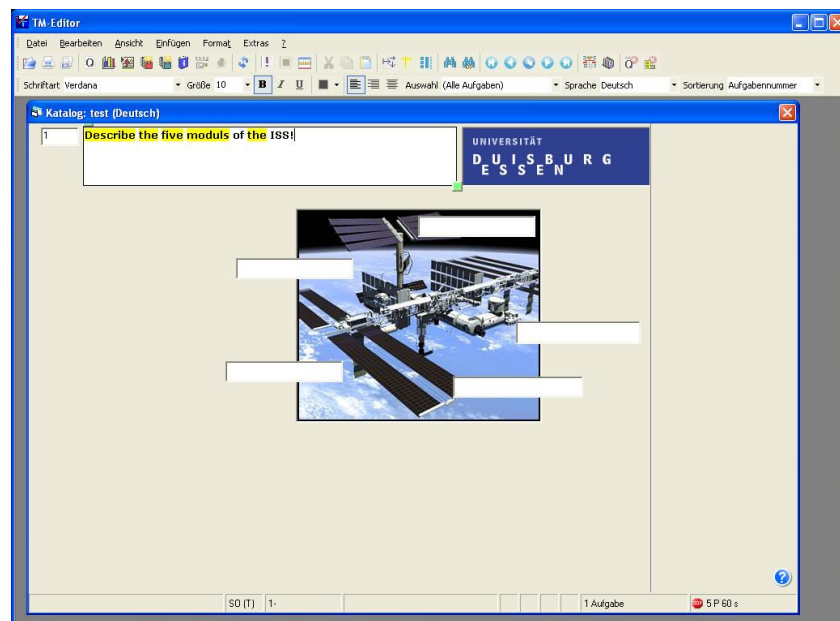**Figure 3: Authoring of Multiple-Choice Questions in the TM-Editor**

Figure 4: Authoring of Open Questions with Multimedia Assets in the TM-Editor

5.4. Web Front-End

In an exam scenario, the participants open a URL in the Microsoft Internet Explorer web browser and log on with temporary login ids generated by the system (see Figure 5). These ids can be printed and handed out to each participant at the beginning of an exam. This step can be combined with the participant's identity check. Then, students are seated. They start the pc, open the web browser (Internet Explorer), and can log on to the e-assessment system. After a successful authentication, the exam is started by the participant. Once started, a timer is displayed showing the remaining assessment time. The software logs every grade-relevant interaction on a per-user basis with a timestamp on a central database. Therefore, in case of a PC client failure, any ongoing exam can be restored in its last saved state and with the remaining time at another desk.
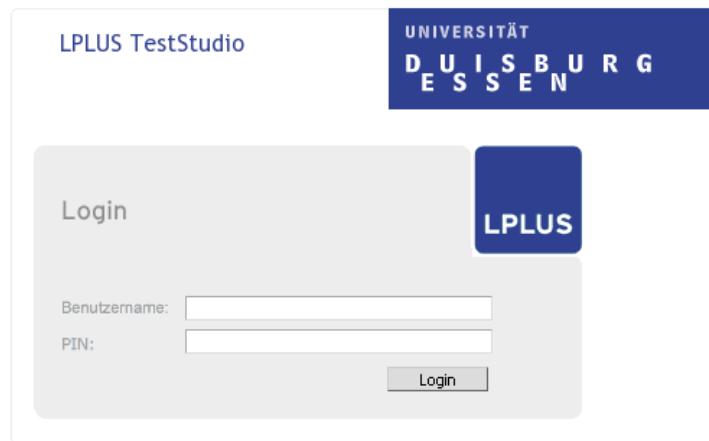
Figure 5: LPLUS web frontend (Login screen)

5.5. High availability

High availability on the server side is achieved through a secondary stand-by server that also serves as the database mirror. In the (unlikely) case of a server failure, the database mirror becomes the database master and the web server is activated on the stand-by system. Then, each participant can logon to the system again and continue taking the exam from the last saved state and with the same amount of remaining time. On the client side, MS Windows –based PCs with Internet Explorer are used. These PCs are configured to boot with standardized boot images. Software administration and distribution is configured centrally with CIM's Rembo Software distribution system. Hence, individual software or configuration-related issues can be reduced to a minimum.

5.6. Exam delivery (publication and distribution)

For a PC-based exam scenario, there are various technical anti-cheating methods at hand. Tests can be permutated and randomized on-the-fly, based on an identical pool or even on disjunctive pools of questions. In addition, the availability of disjunctive question pools can be used for asynchronous exam scenarios with two or more groups that take the exam after one another. By distributing the exam delivery among additional pc halls, there is virtually no limit in the number of participants. However, there must be a sufficient amount of disjunctive questions in the pool and staff for supervision. These techniques allow the production of several versions of an exam that cover identical fields of knowledge at a very low cost, as compared to a similar non-digital production process.

5.7. Grade transmission

As a potentially digital-only process, the e-assessment solution was integrated in the bouquet of digital business processes at the University of Duisburg-Essen, which run primarily on ERP software by HIS GmbH for exam and grade administration. A data import filter for HIS/QISPOS compatible Excel tables allows staff to upload participant lists. The evaluation within LPLUS delivers results as percentages, which are inserted into these Excel tables. Thereafter, the results can easily be interpreted as grades and the Excel tables (with final grades) can be uploaded back into the university's HIS/QISPOS campus management database via a web-based interface. Thus, the grade transmission is also implemented as a digital process and, therefore, the entire process chain is digital. However, the mapping of percentage intervals to grades must be done by the exam responsible according to the examination regulations of the degree program.

5.8. Going Large-Scale: The PC hall

Although the E-assessment solution presented here can be used with small groups of participants, a large multi-purpose PC hall is a mandatory asset for this project. Due to legal safety regulations, the capacity of the PC hall is limited to 196 seats for 178 persons (cp. Figure 2). Scenarios for larger

groups would have required different capacities for the fire escape paths, leading to excessively higher costs. The PC hall is to be established in an existing on-campus facility that is undergoing renovation. It will be equipped with floor coatings with low electric conductivity, air conditioning, an on-site server room, lockers, a staff desk, two beamers, loudspeakers, 196 multimedia pc desks, chairs and 198 PCs (each including a 19'' TFT displays, mouse and keyboard).

The furniture was especially selected for a multi-purpose scenario. The TFT displays are mounted below the desks, under translucent glass plates that are fixed in the centre of each desk (Figure 6). Hence, the desk can be used for both pc-based and "pen & paper" activities. As a side effect, the location of the displays prevents them from intentional and unintended movement and destruction. The glass inlays are strengthened to withstand physical stress and are optimized for low light reflectivity. The lighting will be both direct and indirect.

Figure 6: Placement of computer peripherals on two types of furniture

The process of finding the "right" furniture has been coordinated with the faculties and the authors. Two specimen desks have been placed in a show room for several weeks (Figure 7).

Figure 7: The "show room"

The equipment has been tested and discussed with various university personnel (including authors, students, IT staff). The following check list for functional requirements of the furniture has been compiled from the feedback:

Visibility of TFT displays

Legroom under the desk (considered for both humans and chairs)

Accessibility of mouse and keyboard (in E-assessment scenario)

Disturbance factor of mouse and keyboard (in "pen & paper" scenario)

Impact of the transition glass inlay / desk surface (during handwriting in "pen & paper" scenario)

Accessibility of the power-on buttons (PCs & TFT displays)

Accessibility of the pc and its peripherals (for maintenance)

Impact of furniture during software delivery and distribution (for maintenance, if applicable)

Furniture in accordance with fire protection requirements (materials, alignment in room layout)

Amount and location of power outlets per desk

Cable routeing and its accessibility in case of maintenance

Visibility of neighbouring TFT displays (less important if question permutation is used)

Airflow (for PC cooling)

Scalability of the furniture system (i.e. for cost reduction)

Existing best practises

The list is limited to furniture-related aspects only. It does not cover other potential constraints, such as, environmental ones (heating, cooling, lighting, electricity) or facility-related ones (mandatory alternative usage scenarios, bearing / non-removable building parts, safety restrictions). The re-opening of the renovated PC hall is scheduled for the winter term 2009/2010.

6. BUDGETARY SUMMARY

The project's budget includes hardware (130k€), software (150k€), furniture (80k€), and construction works (750k€) and results in a total of 1.11 m€ (see Table 1). The LPLUS software package includes the server-sided program logic and unlimited client access licences for PC clients of UDE students and staff, campus-wide licences for the TM-Editor authoring tool, premium support (phone and E-Mail hotline for authors), and on-campus courses for authors and administrators. In addition, LPLUS attends on-campus early adopters' workshops that are held to communicate best practices and experiences with the system.

Table 1: Financial budget (Overview)

Hardware	196 PCs + TFT displays	100.000,- €
	2 servers	10.000,- €
	Network devices	20.000,- €
Software	MS SQL Server & LPLUS	140.000,- €
	Data filter LPLUS/QISPOS	10.000,- €
Furniture	190 PC desks	80.000,- €
Facility	Renovation + extension	500.000,- €
Federal facility agency (BLB)	Fee	250.000,- €
Total:		1.110.000,- €

7. CONCLUSION AND OUTLOOK

We have presented the system design and delivery strategy of an e-assessment solution based on LPLUS at the university of Duisburg-Essen. Current activities focus on the renovation of the facility reserved for the PC hall. In addition, we currently test the new Moodle data import filter by LPLUS that allows authors to import some question types of existing Moodle catalogues.

8. Acknowledgements

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