CORVINUS UNIVERSITY of BUDAPEST

Doctoral School of Economics, Business and Informatics

COLLECTION OF THESES

Ágnes Meleg

Comprehensive competence assessment in higher education relying on learning analytic methods and techniques

Ph.D. dissertation

Supervisor:

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Department of Information Systems

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Contents

1. Motivation and research background

Competence assessment can be challenging in several respects, especially in higher education (HE) due to the various programs, learning paths, goals, and student profiles. Still, there is an ever-increasing need for competency-based summative student assessment, with extreme attention to 21st-century skills, such as communication and collaboration (e.g., Burns et al., 2018; Cummings et al., 2020). Although many studies have been conducted on this subject, there are still limitations and unresolved questions. In spite of years of shifting towards competency-based curricula, few researchers have designed assessment systems in higher education that specifically evaluate competence-focused teaching approaches (Brauer, 2021).

There is no single universally accepted definition of the concept of *competence*, however, in general, **in educational evaluations, the term competence is associated with complex combinations of abilities and skills that are needed in specific, real-life situations**. As a result, competence assessment tools must also properly represent a specific area of the relevant, real-life situations (Hartig, 2008).

Simulations could be greatly leveraged in assessment efforts, as they effectively support learners to apply their prior knowledge in realistic situations, endorsing their complex skills (Chernikova et al., 2020). In higher education, especially at the end of their studies, students should be prepared for their future profession, and their professional competencies should involve a range of complex skills. Simulations create a scenario-based environment, where students undergo interactions to apply previous knowledge and practical skills to real-world problems (Vlachopoulos & Makri, 2017, p. 4).

From another perspective, simulation is an educational tool to support reflection and reflective practice (Husebø et al., 2015). *Reflection* is a process of learning from experience, considering, evaluating, and building upon previous knowledge in light of these experiences, and then incorporating this new knowledge to inform future practice (Husebø et al., 2015, p. 1). Based on Schön's theory (1983) one can distinguish between *reflection-in-action* (learning by doing) and *reflection-on-action* (learning from the event later, upon reflection). Activities to bolster reflection are being promoted and incorporated into education, helping students to be ready for professional practice (Horn & Vetner, 2021).

Assessment efforts could be highly supported by *learning analytics* (LA); as assessment and learning analytics can have positive exchanges in both directions and in different forms (Gašević et al., 2022). The fast-growing, multi-disciplinary field of learning analytics is most frequently defined as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (Long et al., 2011, p. 1).

There are many techniques, such as predictive methods, relationship mining, statistics and visualization, discovery-with-models approaches, and clustering techniques (Viberg et al., 2018). Clustering is commonly used in learning analytics, covering all kinds of educational research areas, such as learning behavior (e.g., Križanić, 2020), student strategies (e.g., Vaessen et al., 2014), and learning performance (e.g., Yang et al., 2022). Apart from technicalities, one important angle of LA is the human factor (Shum et al., 2019); in view of *human-centered learning analytics* (HCLA), the researchers should pay special attention to key stakeholders when applying learning analytics.

This research builds on the above-presented definitions, with the aim to conduct a competence assessment, suggesting novelty in terms of the simulation assessment itself and the use of learning analytic methods and techniques to analyze the (trace) data generated during the simulations for assessment purposes (in combination with other data sources – e.g., peer review). In this research, a certain group of students has been targeted, however, with a generic approach the solution could be leveraged in other programs of any other educational institution.

The research project had three main phases – planning, execution, and control –, to address the following main research questions:

A) How can an **individual competence assessment**, which places students in a **real work situation**, be carried out **effectively**?

aa) How can we ensure that we get a **comprehensive picture** of the competencies (or expected learning outcomes), without measuring each competency with a separate method and tool?

ab) How can we verify whether the competence assessment gives **reliable** results that can be **clearly interpreted** by those involved?

B) How can the data and results of the established competence assessment be **utilized**?

2. Research methodology

The exploratory, multidisciplinary research consisted of several project phases (See Figure 1) relying on a mixed-method approach (both quantitative and qualitative methods) – following the guidance of Viberg, Hatakka, Bälter, and Mavroudi (2018). The research targeted a particular group of students of the Corvinus University of Budapest who were at the end of their Management Information Systems bachelor studies. In the light of human-centered learning analytics, the students were involved in the research as much as possible, at different stages of the project.

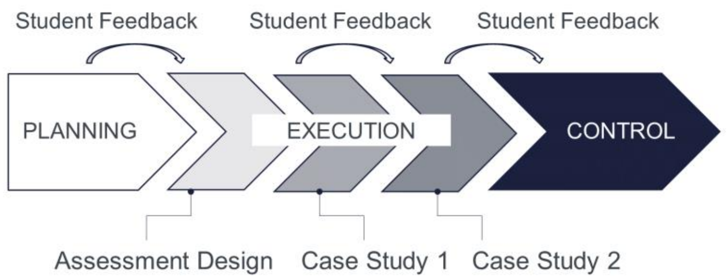

Figure 1. Project phases

2.1. Research to support the competence assessment development

In the first phase of the research, in addition to the literature review, I relied on questionnaire data collection. The purpose of the survey was to identify what aspects should be taken into account in order to answer question A) of the research.

The basis of the research was a voluntary, anonymous questionnaire survey among graduating students of Management Information Systems at the Corvinus University of Budapest, as well as the professors who taught them. The student questionnaire covered three main parts: i) experiences and opinions related to competence assessment, ii) competencies related to the program (ranking in order of importance), iii) studies and future career ideas, and demographic data. The modified version of the professor questionnaire, reflecting the above, was as follows: i) opinions related to competence assessment, ii) evaluation of competencies related to the program.

The base of the competency list examined in the questionnaire was given by the competency list published in the *18/2016. (VIII. 5.) decree "IV. Informatics area 1. Bachelor's degree in Management Information Systems"* (Hungarian Ministry of Human Resources, 2016).

2.2. Presentation of the comprehensive student competence assessment

The competence assessment was developed as a result of the literature review and the presented survey, in the form of a 3-hour online simulation with embedded questionnaires.

In total 160 students participated in the assessment: the first case study was conducted in December 2021 (n = 80), and it was followed by another in May 2022 (n = 80). All students gave their consent to analyze their data – considering ethical concerns. The data were collected from two platforms: a communication and collaboration platform, and a survey platform.

Table 1. Measured program-specific competencies

Competency	Description
Ability 1	Prepare solutions to economic problems in cooperation with business and IT specialists, and provide IT support and development initiatives
Ability 2	Understand and analyze business processes, create requirement specifications for software applications, and perform basic programming tasks
Ability 3	Help the adaption of economic applications, initiate organizational changes required for the introduction of IT applications, and cooperate during implementation
Ability 4	Explore the operating conditions of applications, weigh and communicate the benefits, threats and risks
Ability 5	Perform database management related tasks, and execute basic data migration tasks
Ability 6	Apply system development principles and methods, and use development tools
Ability 7	Explore and research problems specific to information systems, and identify and collect the necessary resources
Ability 8	Operate economic applications and provide user services
Ability 9	Plan and manage smaller development projects
Ability 10	Resolve IT conflict situations in economic environment

In the assessment program-specific abilities (See Table 1), as well as generic skills – 4Cs: collaboration, communication, critical thinking, creativity –, have been included.

Framework and design process

The research project relied on the presented framework (See Figure 2). As a starting point, competencies to be included in the assessment were identified based on the centrally defined student learning outcomes (Hungarian Ministry of Human Resources, 2016).

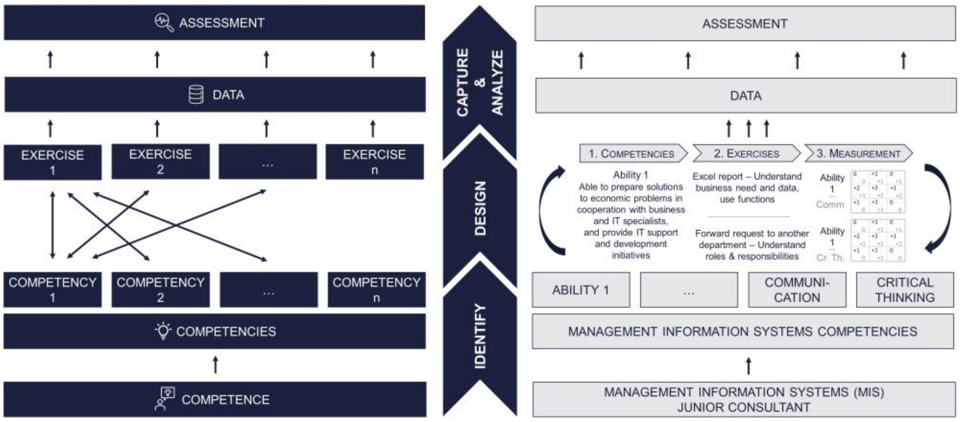

Figure 2. Framework – Schematic example

In the design phase, first, the program-specific competencies were taken, and – through several creative brainstorming sessions – exercises were developed to be able to assess them. With one exercise various competencies could be assessed simultaneously, and one competency could be assessed through several exercises (many to many relations) (See Figure 3).

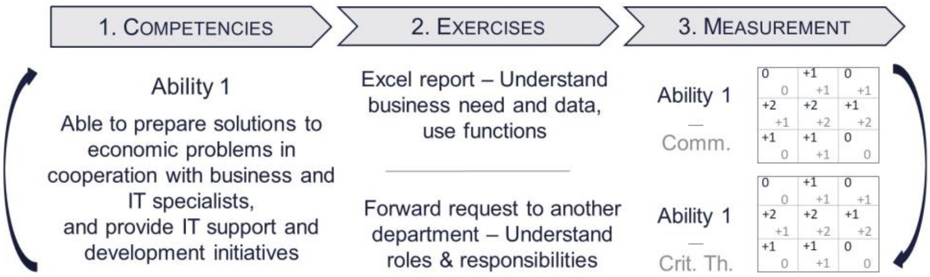

Figure 3. Exercise design process

After exercise design, multiple answer options were created that were all different: e.g., one optional answer was stronger in terms of communication but less strong technically, whereas another option was stronger in terms of technicalities but less strong communication-wise. Finally, different scores were assigned to each answer depending on the content. (10 exercises were created this way, with a total of 90 answer options.)

As a result, in the last phase, data could be easily captured, analyzed and turned into meaningful insights for assessment.

Schedule and exercises

According to the simulation scenario, the students work for a fictional company, *Vision Consult*, as MIS Consultants in the EMEA region. They work in small teams, in various locations, receiving requests on a daily basis from colleagues and clients. Requests come from four imaginary companies: *Nuria Bank* (financial services), *TLC* (telecommunication), *Talent4U* (recruitment and staffing services), and *P3 Project Consultancy* (project management consulting firm). All external requests arrive through the simulated CRM system, and an internal request is sent to their "inbox" from an "HR colleague". The exercises cover the areas of Management Information Systems, and some of them are connected, therefore, the participants have the chance to familiarize themselves with the personas, understand their business needs, and get an insight into the different industries.

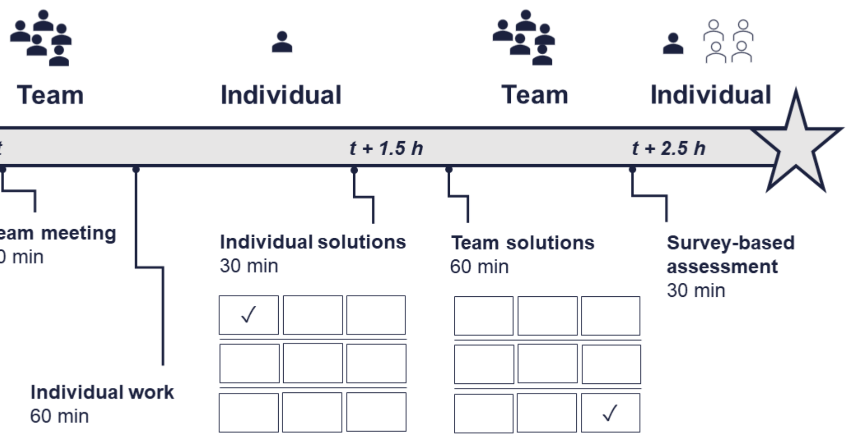

Figure 4. Schedule

The 3-hour assessment event was made up of several sections (See Figure 4). Students were informed about the schedule through a guide, and besides a Q&A channel and a coordinator helped them in navigation. The students communicated and collaborated through MS Teams. There was a general channel, where all the requests arrived with a unique identifier and a link, redirecting them to request details. All students were also added to a sub-channel randomly (of 4-5 participants, according to their ”location”, such as Athens, Brussels, or Cairo), where they cooperated with one another by posting, reacting, and initiating video calls.

The participants had one hour to work on the requests **individually**, after having an introductory call with their team. Once the time was up, the students got access to a questionnaire platform where they provided their solutions in the following way: related to each request students received 9 answer options (including possible answers to the requestor or a series of actions they would do) from which students had to select one, in an interactive way, based on their preliminary work. The students had 30 minutes to select an option for each request. Every option equaled different scores considering the measured competencies, for example in a certain exercise Option 5 could mean a maximum of 6 in total *(Ability 1*: 2; *Ability 8*: 2; *Communication*: 2) whereas, Option 9 only 2 (*Ability 1*: 1; *Ability 8*: 1; *Communication*: 0). Once finished, students had another “team meeting” with their “local team members” to discuss their approaches and decide the preferred option on the **team level** as well, as a team consensus.

Self- and peer assessment

In the last section of the event, the participants received a questionnaire to assess themselves and their team members on a 0-100 visual analog scale, for each competency.

Data collection

For the analysis I had 3 main data sources: i) MS Teams – digital activity data, ii) Qualtrics – answer sheets with choices, and questionnaires, iii) MS Excel – mapping table of answer options, exercises, and competencies.

<u>MS Teams</u>:

From MS Team digital activity data set was downloaded utilizing the feature of Insights (See Table 2 – the individuals' names were removed due to data protection).

Table 2. Extract from digital activity data (MS Teams Insights)

Name	Email address	Channel	Posts	Replies	Reactions
X	...@stud...	Paris	0	1	0
X	...@stud...	QA	1	0	0
Y	...@stud...	Edinburgh	0	1	0

<u>Qualtrics</u>:

From Qualtrics four different data sets were downloaded: i) individual solution – answer sheet (See Table 3), ii) team solution – answer sheet, iii) self- and peer assessment – questionnaire, iv) event evaluation – questionnaire.

Table 3. Extract from answer sheets (Qualtrics)

Student ID	Exc. 1 Option 1	Exc. 1 Option 2	Exc. 1 Option 3	Exc. 1 Option 4	…	Exc. 1 Option 9
ID_X	Neutral	Neutral	Dislike	Neutral	…	Like
ID_Y	Neutral	Neutral	Dislike	Neutral	…	Neutral
ID_Z	Neutral	Like	Neutral	Neutral	…	Neutral

<u>Mapping table</u>:

Prior to the event, the working group defined the scores for each answer option in each exercise, mapping them to the measured competencies (See Table 4). (For the actual simulation the options were mixed.)

Table 4. Extract from the original mapping table

Exc.	Competency	Opt. 1	Opt. 2	Opt. 3	Opt. 4	…	Opt. 9
1	Ability 1	0	0	1	0	…	1
1	Ability 8	0	1	1	1	…	1
1	Communication	2	2	0	2	…	0

2.3. Evaluation of the comprehensive student competence assessment

As a first step to evaluate the competence assessment, I turned to descriptive statistics. I examined the distribution, and then I analyzed both the individual and the group results to gain an insight into student competencies: which areas need improvement and which competencies the students are stronger in. Furthermore, I analyzed the self- and peer evaluations.

After that, I carried out further research to evaluate the competence assessment in order to get a comprehensive picture: on the one hand, I applied IRT (Item Response Theory) modeling, and on the other hand, I studied the student opinion.

IRT modeling provided an opportunity for a deeper study of the assessment. The IRT models show the relationship between an ability or trait (θ) examined by a certain study and the related items: in this case, this refers to the relationship between the MIS competence – as a latent variable – and the related competencies specifically examined by the competence assessment exercises. There are several types of IRT models, including three-parameter, two-parameter, and one-parameter logistic dichotomous models, as well as polytomous models.

In this research, I used the polytomous GRM model (Graded Response Model), as in the case of the data collected during the simulation competence assessment, we can talk about multi-valued variables. During the analysis, I studied the competence assessment as a whole, as well as the effectiveness of the measurement for individual competencies.

As to the student opinion, after the competence assessment, I asked the students to evaluate the event anonymously in a short questionnaire, by finishing the sentence "The competence assessment through online simulation was...": i) difficult, ii) beneficial, iii) relevant, iv) enjoyable. Besides that, the students could add text comments. In addition, a focus group was conducted to further deepen the understanding of the students' opinion.

2.4. Utilization of the comprehensive student competence assessment

The competence assessment utilization was examined from the perspective of both students and professors. I processed and analyzed the assessment data, relying on learning analytic methods and techniques.

One of the main areas of use is the feedback to students about their competencies. Human-centered learning analytics (HCLA) is a subfield of learning analytics, with a strong emphasis on the individual, therefore, HCLA is often supported by a qualitative research method, such as focus group, which is particularly well-suited for exploring a certain topic, the focus.

In light of HCLA, a student mini-focus group was conducted to gain further insights into how the students feel about the competence assessment, as well as what kind of feedback they prefer. The final goal was to create a student dashboard based on the results of the discussion.

In addition, professors and other decision-makers could also benefit from the information gained from the competence assessment data. To support this, I performed several statistical analyses on the simulation data, as well as on the self- and peer assessment data. The cluster analysis gave me a more detailed picture of the competencies among individual student groups.

In addition, I examined whether there was any correlation between i) the competence assessment result and the acquired work experience, and ii) the competence assessment result and student organization participation.

3. Results of the thesis

3.1. Preliminary research results

The student questionnaire related to competence assessment was completed in the spring of 2021, with the participation of 132 students. **The most important result was the interest in competence assessment**: 92.4% of the students stated that in their opinion carrying out competence assessment within the framework of the program would be beneficial. In the fall of 2021, the 22 professors who filled out the questionnaire also expressed a positive opinion: 95.5% believed that it would be beneficial to carry out competence assessment in some form. In addition, the survey covered the opinions about the competencies connected to the program – the students and the professors were in close agreement in this regard as well.

3.2. Competence assessment results

A total of 160 students participated in the competence assessment, 80-80 on both occasions.

As the first step of the analysis, I performed calculations in MS Excel and R Studio, for which preliminary score calculations were made based on the following steps:

1. Total scores, at the individual level;
2. Competency level detailed scores, per individual;
3. Total scores, at the team level;
4. Competency level detailed scores, per team;
5. Self- and peer assessment scores at the individual level, per competency.

After that, I examined the distribution of the data with regard to the individual total scores: **normal distribution could be observed in both cases** – Shapiro-Wilk normality test: $p_{2021} = 0.6917$, $p_{2022} = 0.3764$.

As a next step, I studied the results of the simulation at the level of each competency and then compared them with the results of the self-assessment and peer evaluation. **Based on the simulation, the student's strengths and the areas of improvement were well outlined**; for example, based on the first assessment – in terms of skills – communication as a student strength and creativity as an area of improvement, and in terms of abilities, abilities 4 and 6 as strengths and ability 2 as an area of improvement could be identified. The same cannot be said based on the self- and peer evaluation: **the students could not precisely differentiate when evaluating themselves and their peers**, especially regarding abilities. Furthermore, it can be stated that during the self-evaluation, the students were generally confident in their statements, while in the case of the peer evaluation, they gave a slightly stricter evaluation.

In addition, an outstanding result is that in the case of the team solutions – which occurred after the individual solutions –, the students achieved a higher score on both occasions, so **the participants learned from the competence assessment, and the reflection linked to the simulation already took place during the event**.

Furthermore, I also conducted explanatory analyses: I examined factors that might be related to the outcome of the competence assessment. Thus, during the individual assessment, the students indicated how many months of work experience they had, as well as whether they had ever participated in a student organization (yes/no), however, the analysis did not demonstrate a significant relationship (work experience: $p_{2021} = 0.3011$, $p_{2022} = 0.9541$; student organization participation: $p_{2021} = 0.773$, $p_{2022} = 0.66$). In light of this, a potential research direction could be what factors could be related to the student competencies of the HE program.

3.3. Student cluster analysis

To gain a deeper insight into student profiles, I applied clustering techniques. Three sets of data were analyzed: i) individual-level data from the simulation results, ii) self-assessment data, iii) peer assessment data.

I followed the same steps in each case. I loaded the data table from a CSV file into the 4.2.2 version of R, then after selecting the necessary data elements and cleaning the data, I normalized the data. Since the variables were numerical performance scores, I normalized them to have a mean of 0 and a standard deviation of 1. I used both the k-means algorithm and hierarchical clustering, then multidimensional scaling (MDS) was applied to visually illustrate the clustering results – by reducing the dimensions of the original variables to two dimensions. Finally, I identified clusters from all three data sets and compared the results with each other.

Different student groups were identified by the cluster analysis; the students' self-assessment and peer assessment gave different results compared to the simulation – confirming the previous analyses. **The result of the simulation presented a much more complex picture of the students' competencies**; on the one hand, students tended to overestimate their competencies, and on the other hand, they could not provide as nuanced a picture as the simulation. **While, as to the analysis of the simulation, the groups were formed based on a certain combination of the competencies, on the basis of the self- and peer assessment, the clusters were typically only formed along the direction of judgment from more positive to less positive in general**.

3.4. Application of the IRT model to evaluate the assessment

For the overall analysis of the competence assessment, I applied an IRT model. For this – in order to conduct a general examination of the competence assessment – the first step was to aggregate the two data sets (2021 and 2022), for which I first performed a relationship analysis.

After that, I used a GRM model (Graded Response Model) for the joint analysis, considering that we can talk about multi-valued variables for the individual competencies.

As the first part of the analysis, I examined the individual competencies, during the study θ is the latent variable to be measured – in this case, the MIS competence – and the items are the observed variables – in the present study, the individual sub-competencies. I applied fit analyses, first for the model as a whole, then for the individual items and also the individuals.

After that, I used information curves for the competency-level evaluation, as well as for the assessment as a whole.

As a result of the analyses, it can be said, among other results, that *Ability 6* differentiates the best, while *Ability 2* differentiates the least. Regarding the fit of the model, it can be concluded that most of the elements fit well, and the fit of the individuals is good by observing the infit and outfit statistics. Based on the information curves, the assessment is more accurate in estimating low θ values and less accurate in estimating high θ values; therefore, **the competence assessment measures well overall, with the limitation that it is less suitable for very precise differentiation of students with higher competencies**.

3.5. Student feedback

Student feedback took place at several levels: in the form of a questionnaire after each assessment, then with a focus group to go over the method of feedback related to the assessment results.

The student event evaluation questionnaire was anonymous. After the first assessment 70 students answered the questions (87.5% response rate), and after the second assessment 69 students (86.3% response rate). As to the focus group, a total of 5 students participated.

Questionnaires

The data of the comments (n_{2021} = 39; n_{2022} = 42) belonging to the questionnaire were manually analyzed, labeling each statement according to content and mood (e.g., time, +/-). After the first assessment, the students gave both negative and positive feedback. Negative feelings were expressed about the time provided, as well as communication and guidance. However, many positive opinions were also received regarding the simulation experience.

After the second assessment, the constructive criticisms were also related to the guidelines and the available time, however, in terms of proportions, there were many more positive comments compared to the previous survey, and the students still valued the simulation experience the most, for example:

„The problems were relevant, quite difficult and enjoyable. It felt like a real working environment with the teams and the individual work. All-in-all a fun and useful event."

The average questionnaire values on a 0-100 scale were as follows: difficult_{2021}: 74.8; beneficial_{2021}: 56.1; relevant_{2021}: 61.5; enjoyable_{2021}: 53.7; difficult_{2022}: 72.3; beneficial_{2022}: 76.7; relevant_{2022}: 77.9; enjoyable_{2022}: 72.2. **The small changes made between the two assessments had a positive effect on the students, as confirmed by both the numbers and the comments.**

Focus group

The basis of the focus group discussion was provided by a report showing the results of the competence assessment of two fictitious students. One of the main results of the guided discussion was **the confirmation of the positive opinion formed about the competence assessment as to the simulated company environment**, and the other was the conclusion of ideas of how to transform the initial report into a more complex student dashboard. **As a result of the latter, a current form of the dashboard was created through student work.**

4. Summary

The primary objective of the research was achieved: the development of an innovative competence assessment for higher education students, which requires relatively little resources and could be leveraged in other programs as well.

The comprehensive competence assessment developed as part of the research is suitable for measuring several competencies at the same time – the current version is focused on MIS competencies, but not exclusively. It is based on a combination of self-report assessments (self- and peer evaluation) and real-time exercises.

Based on the participants' opinion, it can be concluded that the students value the initiative, this is confirmed both on the level of numbers and by looking at the student survey comments. The application of the IRT model provided the possibility to evaluate and validate the assessment: the competence assessment measures well overall, with the limitation that it is less suitable for very precise differentiation of students with higher competencies.

The result of the competence assessment can be utilized in several ways within the HE program, especially if the assessment is fully integrated into the program curriculum and thus repeated several times during the studies, each time being adjusted to the academic progress.

The assessment can support both institutional and individual goals. Through the competence assessment, it is possible to identify which areas of competence should be emphasized more during program development. The clustering results provide an opportunity for more personalized learning paths and more effective project work. For example, by mixing students from different clusters, groups with a broader competence profile would be created, and the students could benefit more by learning from each other. In addition, the simulation can be used as an educational tool, providing students with a reflective experience. Individual goals are supported by the student dashboard, and – as students are close to finishing their studies –, they could also receive career advice related to the results of the assessment.

With the exploratory, multidisciplinary research presented in the dissertation, it was possible to answer the research questions and fulfill the goals. The developed competence assessment provides guidelines in relation to the first main research question, namely „How can an individual competence assessment, which places students in a real work situation, be carried out effectively?”, and then the related studies gave an answer to the question „How can the data and results of the established competence assessment be utilized?”. Thanks to the general approach and framework, other programs of other institutions could benefit from the research as well.

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6. Dissemination

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Ágnes Meleg: Competence Assessment in Higher Education; a Case Study of the BIS program at BCU

LASI 2022 - Learning Analytics Summer Institute Spain 2022 – Spain, Salamanca, 20-21 June, 2022

Ágnes Meleg: Student Competence Assessment in Higher Education with Online Simulation

LAK23 - 13th International Conference on Learning Analytics & Knowledge – USA, Texas, Arlington, 13-17 March, 2023

Ágnes Meleg: Competency-based summative assessment through online simulation leveraging analytical methods and techniques