CHECKING THE STUDENT'S APTITUDE FOR A BACHELOR PROGRAM: EXPERIENCES WITH A WEB-BASED TOOL

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Abstract

In autumn 2014 the Bachelor of Science programme "Business Information Technology (BSc BIT)" was launched. BIT is about the application of information technology in business with the focus on building information systems. Since the start of the programme it can be observed that a considerable number of students face difficulties in modules related to programming and mathematics at the beginning of the study. In order to help potential applicants of the programme to understand the kind of competencies of abstract thinking that are needed for the BSc BIT programme ahead of the start, a web based self-assessment test was developed. The aptitude test - built with Google Forms - currently consists of 25 predefined multiple choice

questions and calculates an overall aptitude figure by summing up the single aptitude values for the categories logical and analytical thinking, understanding algorithms, mathematics and abstract thinking. The questions are taken from well-established test systems like ELIGO-System, BOMAT, CASA etc. and are typically solved within less than 45 minutes. The students can check their suitability for the study programme by comparing their overall aptitude value with a given threshold. First test runs conducted with the tool confirm the validity of the aptitude test. The future scope will involve more students and deal with an analysis of concrete weaknesses that can be used as input to adapt the settings of programming and mathematics modules.

Keywords

IT-based Aptitude Test, Bachelor Program, Business Information Technology (BIT), Google Forms

1. The Program BIT

Business Information Technology (in German: "Wirtschaftsinformatik") is a field of informatics focusing on how business can be supported with information technology. Therefore, students have to understand business as well as IT to support the ongoing process of digitalization. Students need abstract thinking skills that are involved in the analysis of business needs. For the design of IT systems, they have to acquire the necessary innovation, communication and modelling skills.
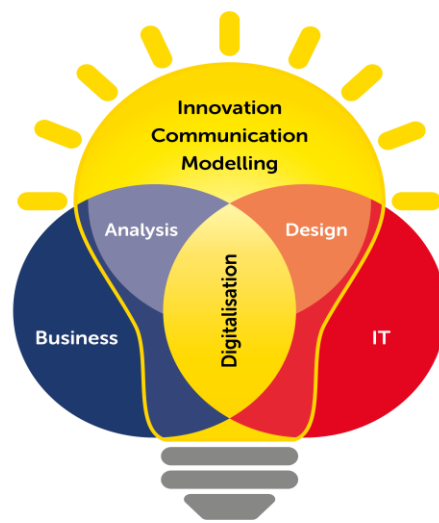

Figure 1: *Design principles of the BIT programme*

In autumn 2014 the University of Applied Sciences Northwestern Switzerland (FHNW) launched BIT as a new Bachelor of Science programme in Business Information Technology (BSc BIT, see Figure 1) completely taught in English. The English programme is equivalent to the successful "BSc Wirtschaftsinformatik" in German that is available since 1999. The goal of the English BSc programme is to foster more international student exchange. The complete programme consists of 180 ECTS points and is equally divided into five different module groups, which are

- Foundations

- Business Administration

- Information Technology

- Business Information Technology

- and student projects

The *foundations* modules include mathematics, communication, ethics and law. In *business administration*, students follow courses in principles of management, accounting, marketing, economics, corporate finance, logistics and corporate strategy. *Information technology* consists of requirements engineering, programming, software engineering, database technology, internet technology, enterprise content management and information infrastructure. *Business Information Technology* covers subjects like business process management, e-business, enterprise systems, business intelligence, IT security and IT management. Through this broad variety of topics, students learn to change perspectives from analysis to design or from business to IT. In the module group *student projects* the knowledge is applied in real world projects with companies or public organizations where they are typically working in project teams of three students or alone during their bachelor thesis. In the end, they have all the necessary skills to lead mixed teams, and are able to talk to business as well as IT to find new innovative business models in the world of digitalization.

At the start of the programme, students have to pass the so-called assessment stage, which comprises the courses Business Mathematics, Principles of Management, programming and Introduction to BIT. Successful passing these courses is a prerequisite to continue the study program.

2. Design and Implementation of the Aptitude Test

As described above, the BIT program is about the application of information technology in business with the focus on building information systems and managing them during the entire life cycle. Since the start of the programme it can be observed that a considerable number of students are facing difficulties especially with modules related to programming and mathematics during their assessment stage. Some evidence shows that it is much more effort for those students coming from a non-technical oriented previous education. However, since our course of studies does not require any programming skills, the students coming from the commercial background do not have any previous experience about their aptitude for programming, which turns out to be one of the lectures that cause, together with mathematics the most failures during the assessment stage. In order to provide some initial insight into the aptitude of the applicants with respect to the required skill set four our course of studies, a web based self-assessment test was developed within the context of a bachelor thesis (Barba, 2017).

There is no specific research about the aptitude of students for BIT-related programs. Taking into account that programming and mathematics are two decisive topics for BIT, we can observe that there is a lot of ongoing research about the aptitude of students resp. predicting the success rate for programming courses (Caspersen, Larsen, & Bennedsen, 2007), (Scott & Ghinea, 2014). Despite some initial claims (Dehnadi & Bornat, 2006) and promising initial results, there exist up to now no really satisfactory insights about which influence factors determine this aptitude (Bornat & Dehnadi, 2008). With regards to dedicated aptitude software, besides a lot of questionnaires there exists a game-based tool MasterMind®, which derives the ability to program based on actions taken in game scenarios (Lorenzen & Chang, 2006).

Up to our knowledge, no validated approach or software is available to assess the aptitude of a student for the BIT programme and we decided to design and implement a solution according to our needs. The next chapter provides a short overview of the stakeholder analysis as well as the functional and non-functional requirements and the subsequent evaluation of a suitable product.

2.1 Stakeholder Analysis

The main stakeholders for the aptitude test are not only the candidates of the Business Information Technology programme, but also the entire faculty, including BIT deans, lecturers as well as the management of the school. In the following table, the relevant stakeholders together with their knowledge and goals are shown. For the elicitation of the requirements,

mainly the BIT deputy dean and selected lecturers (teaching the critical subjects like programming etc.) were involved.

Table 1: *Stakeholder overview*

Stakeholder	Knowledge	Goals
BIT deans and school management	Scope and goals of the BIT programme, statistical information about students	• Attractive program • Sufficient number of students • High satisfaction degree of students
BIT lecturers	Module content	• Reaching the module goals • High satisfaction degree of students • Drop out rate within acceptable limits
BIT program candidates	Basic business knowledge (one year practical experience)	• Program matching with the interests • Good job opportunities
Government (Cantons)	Workforce situation and business economy	• Well-trained employees • Developing digitalization for the Swiss economy
Future employers	Digitalization need	• Well-trained, innovative employees

2.2 Functional and Non-Functional Requirements of the Aptitude Test

Requirements engineering is always the first step in an IT project. This discipline deals with the elicitation, documentation and management of customer needs, which are later on implemented with suitable software tools. Functional requirements are concerned with the functionality of the software. For the IT-based aptitude test, the following functional requirements were defined:

- Public access: The system shall be accessible without prior registration.

- Integration of test questions: The system should provide test questions that cover the necessary abstraction skills used in the assessment stage.

- Checking answers: The system should compare the given answers with the correct solutions.

- Evaluation: Based on the given answers the system should compute an aptitude figure for the BIT program.

- Dashboards: The system should inform the user about the results in an adequate way

- Test characteristics: The test shall not build upon knowledge, which is provided during the programme (i.e. no questions related to BIT module content in order to treat candidate students as equally as possible.

For the project, the following non-functional requirements were defined:

- Corporate Design: The system shall use the current corporate design of the University of Applied Sciences and Arts Northwestern Switzerland (FHNW).

- Usability: The user interface of the system shall be intuitive and enable the students to perform the test without any assistance.

- Reliability: The system shall always create a correct evaluation of the answers.

- Performance: The system shall have response times of max 2 seconds.

- Maintainability: The system shall allow modifying or extending current content with limited effort.

- Privacy: The system shall save the data in an anonymous way. No account or specific application procedure for using the aptitude test shall be necessary. Furthermore all data shall be only stored on FHNW servers (including hosting aspects)

2.3 Test Characteristics

For the success of the aptitude test, a high degree of test validity is indispensable. In our project, the test validity is given if the questions measure the aptitude of the candidates for the *Business Information Technology* programme. In order to reach that goal and to enable an appropriate evaluation, the questions were categorized into test characteristics (Eggerth, 2006).

At first, the predominant characteristics of the relevant topics have to be selected and are discussed in chapter 2.3.1 to 2.3.4 below. They are chosen according their importance.

2.3.1 Logical and Analytical Thinking

This characteristic relates to finding relationships and contexts and to derive unknown knowledge from existing one. Logical thinking can be performed either in a deductive or inductive way.

An example for inductive thinking is the following. Given that there is a logical rule "Dogs bark". If there is a dog named "Jimmy", it is possible to derive the new knowledge "Jimmy can bark" based on strong reasoning. Appropriate questions for BIT candidates may include numerical tasks, analyzing business processes and flowcharts in programming. For this characteristic, we used representative questions from the test systems ELIGO-System (Eligo GmbH, 2018), Pro facts-test system and shapes.

2.3.2 Abstract Thinking

Abstract thinking describes the ability to omit details and reduce the available information to the essential. In computer science, this ability is for example necessary to create a correct object-oriented design or an adequate data model.

Let us take the example of an "animal hierarchy". Categorizing the terms "animal", "golden eagle", "eagle" and "bird" should end up in the class hierarchy (starting with the superclass) "animal", "bird", "eagle" and "golden eagle". For this characteristic, we selected representative questions from the test systems BOMAT (Hossiep & Hasella, 2010), (Hossiep, Turck, & Hasella, 1999) and the core academic skills assessment (Mometrix, 2018).

2.3.3 Understanding Algorithms

Understanding algorithms is the most important precondition for writing computer programs. Regarding the observed difficulties in programming, there is some evidence that students have problems to develop a semantically correct algorithm with pseudo code or a structure chart (e.g. for sorting or finding data, computing prime numbers etc.) and less problems to transform the algorithm into a specific syntax of a programming language like Java, C# or PHP.

Typical questions here are concerned with algorithmic constructs like conditions, loops, variable assignments and functions (with or without parameters). For this characteristic, we selected representative questions from the test systems pro facts- Testsystem and pro facts 360 Degree.

2.3.4 Mathematics

To include mathematics as test characteristic was an explicit request from the BIT program management. This is mainly because students often face difficulties in both programming and mathematics. Obviously, there are some interrelationships between these two areas. For example, formulas in propositional logic correspond to the logical expressions in a programming language. For this characteristic, we did not use questions from existing test systems.

2.3.5 Subordinate Test Characteristics

Besides the predominant characteristics discussed in 2.3.1 to 2.3.4 there are some subordinate characteristics with limited influence on the design of the test questions. Every test question related to one of the predominant test characteristics counts for one point. If a question is additionally related to a subordinate question, it counts for two points. For example, the test

characteristic "understanding algorithms" is introduced shortly with some explanatory text or video. Students need to quickly understand this information in order to find the correct answer. Subordinate test characteristics such as apprehension, creativity, planning, problem solving and velocity have been identified.

- The assessment framework of the aptitude test includes ten questions dedicated to logical and analytical thinking, and five questions in each of the topics abstract thinking, understanding algorithms and mathematics.

2.4 Evaluation of the Software Platform

The implementation of the aptitude test can be done in two ways:

- Alternative 1: Software development: All elicited requirements can be covered and implemented. However, software development from scratch can be quite costly and time-consuming.

- Alternative 2: Using an existing framework: With this approach, you are evaluating different existing solutions and select the platform, which best fits your needs.

Mainly because of time and skill constraints, alternative 2 was chosen. A first shortlist of possible candidates did include Google Forms, Windows SharePoint and Moodle. All of these platforms meet our core requirements of the test namely to be able to include own questions, define suitable response formats and to support the evaluation of results.

Before the final decision, the different platforms were evaluated in further detail based on functional as well as non-functional requirements.

Table 2: *Evaluating functional requirements*

Functional requirement	Moodle Docs	SharePoint	Google Forms
Integrating test questions	ok	ok	ok
Checking answers	ok	ok	ok
Correct evaluation of answers	ok	ok	ok
Visualization of results	ok	ok	ok
Saving results for external users			ok

The functional requirements are only fully met by Google Forms. Moodle as well as SharePoint got a lower rating for the non-functional requirements. The prototype was implemented with Google Forms. The feature to provide individual ratings and to support further analysis of the individual results of the test persons were the key criteria. However, it has to be

mentioned that the implementation is prototypical in a sense that the feasibility of an aptitude test for the BIT program has to be evaluated first. Important non-functional requirements related to security and privacy has explicitly not been considered in this early project phase and may lead to a different tool selection for a fully operational platform.
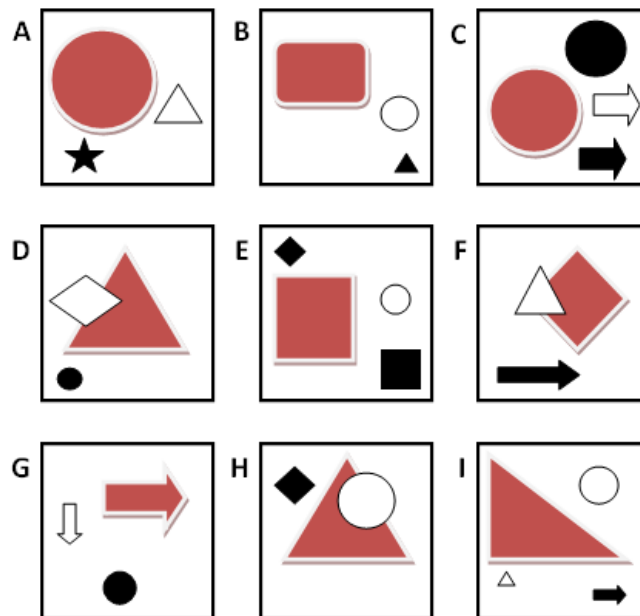
2.5 Implementation with Google Forms

After selecting the relevant categories and compiling the initial set of questions, the next step was to design and implement the questionnaire with Google Forms that has to follow the corporate web design guidelines of FHNW.

Below three representations of test questions are shown as they appear in the categories logical and analytical thinking, understanding algorithms and abstract thinking. None of the questions require previous knowledge about Business Information Technology. Most of the time, participants have to respond to questions by selecting one solution out of a given set of answers as shown in Figure 2.

Figure 2: *Test question from the logical and analytical thinking category*

Figure 3: *Test question from the abstract thinking category*

Initial tests with around 60 participants from different backgrounds have proven the feasibility of the test. The time needed for answering the questions was mostly between 30 and 45 minutes. Personal discussions revealed that some only answered the questions and did skip the introduction videos. The videos have been added, because the test should not only evaluate a final number that indicates the aptitude for the BIT course of studies, but also should provide some insight into the field of studies and underline the importance of *Business Information Technology* skill set for the business world.

3. Application of the Aptitude Test and Validation of Initial Results

In the following sections, we explain the usage of the aptitude test in the context of our BSc BIT course of studies as well as how we analyze and evaluate the test results in order to prove its validity as an indicator of the student's aptitude to pass the assessment stage of the BSc BIT program.

3.1 Purpose and Usage of the Aptitude Test

Some questions in the aptitude test come from question collections that are commonly known as IQ test. Many people are skeptical about IQ tests, because of the potential misuse to reduce a person's intelligence to a single number. To circumvent such an effect for the aptitude test, we searched for a simple way to measure the aptitude on one hand, without compromising

the anonymity of the participants on the other. In order to combine both requirements, participants are allocated to different control groups, which in turn are based on the performance results of previous exams. We focus on the grades in programming, mathematics and the course introduction to business information systems, which all three are responsible for the most failure rates during the assessment stage of the BSc BIT program. The result of the aptitude test should serve as an indicator for the aptitude for passing successfully the assessment stage. The modules evaluated as part of the assessment stage are in turn selected as being representative for the fundamental ability to be able to pass all courses of the BSc program. At the same time, the test should

- Be attractive for potential students and provide some insight into the field of BIT
- Provide an opportunity to participate in a longer test under some pressure and
- Serve as an indicator towards the aptitude of abstract thinking.

All three aspects combined should serve as an indicator to the necessary skills to pass the critical exams of the assessment stage at the end of the first semester.

3.2 Information Events

In BIT, many of our students come from an apprenticeship with a background of either IT or business. This vocational education system is very common in Switzerland since a long time, but is new to many of the international students, which mainly focus on universities and not on universities of applied sciences. Some students also come from a supply school where they graduated with a *Matura* or an *International Baccalaureate*. Most students do not have a single wish of choosing their dedicated program and university, but take multiple options into their shortlist of potential studies. Therefore, it is quite common, that universities provide some information events. In BIT we provide, in addition to information events, the possibility of open days, where interested students can join particular taster lectures in introduction to BIT, programming and mathematics. During these open days, not only the English based programs *BSc BIT* and *BSc International Management* but also the German speaking programmes of *BSc Wirtschaftsinformatik* and *BSc Betriebsökonomie* are open for test lectures. The link to the aptitude test is distributed to the participants after these events.

3.3 Student Grades of the Assessment Stage and Allocation of Control Groups

As mentioned above, students typically fail the assessment stage due to the courses mathematics, programming and introduction to BIT. The following graph shows the distribution of the grades from the years 2014-2016.
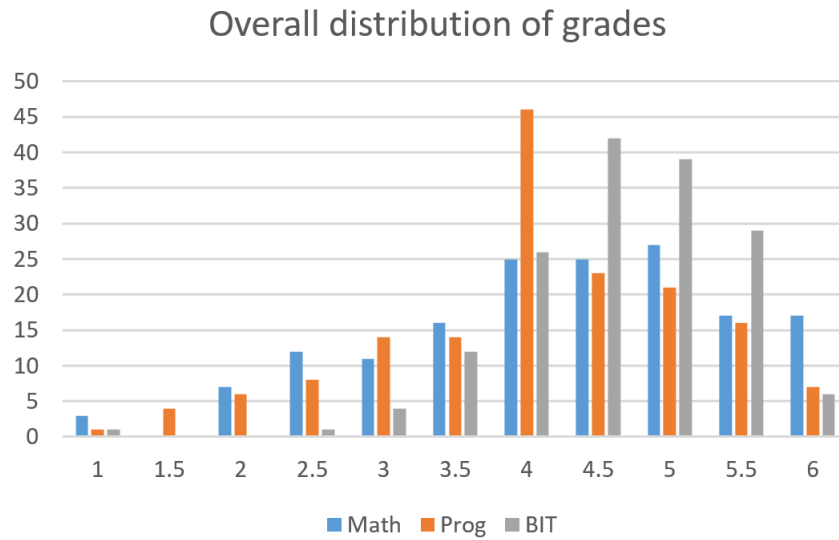
Figure 4: *Distribution of grades of the assessment stage*

As mentioned above, staying anonymous in terms of the test results is one of the non-functional requirements of the test setup. We have introduced different control groups based on previous grades in mathematics or programming related courses. Furthermore, we distinguish between our current FHNW internal students and the potential external applicants that are interested to join the BSc BIT program. The participants were asked about their previous performance ranges

- 5.3 - 6 (best grade)
- 4.8- 5.2 (good)
- 3.8 - 4.7 (meet expectations)
- 3.7 and lower (below expectations)

The participants of the test get their aptitude rating directly at the end of the test. The test results can be evaluated by analyzing the results of the different control groups.

3.3.1 Results of the Assessment Stage

The relatively high failure rate of mainly international students was the origin of the idea to provide the aptitude test. Table 5 shows the outcome of the assessment stage of two BIT classes including the failure rate for Swiss and international students.

Table 3: *Failure rates of international students*

2015	started	current		2016	started	current
Schweiz	**22**	**17**		**Schweiz**	**30**	**17**
Bulgarien	1	0		Algerien	1	0
Deutschland	1	0		Türkei	2	0
USA	1	0		Russland	1	0
Syrien	1	1		Sri Lanka	1	0
Nigeria	1	0		USA	1	0
Slowenien	1	0		Afghanistan	1	0
Estland	1	1		Pakistan	1	0
Abroad Total	**7**	**2**		Serbien	1	1
				Rumänien	1	1
	2015			China	2	0
Failed (CH)	23%			Portugal	1	0
Failed (Abroad)	71%			Italien	2	2
				Ägypten	1	0
	2016			Sri Lanka	1	0
Failed (CH)	43%			Chile	1	0
Failed (Abroad)	79%			Deutschland	1	0
				Abroad Total	**19**	**4**

By comparing the failure rates of Swiss and international students, the figures showed, that the exams were more challenging for international students. Based on some personal discussions with students who failed, the exams were very challenging for them, since it was the first time to have such long exams with more than 20 pages and with a duration of up to 1.5 hours. In this respect, the test is also useful for the participants to test the ability to concentrate for a longer period.

3.3.2 Correlations between Mathematics and Programming

It is commonly known, that some correlations do exist between mathematical and programming skills. However, figure 5 shows that the correlation is less than expected. One possible explanation is that programming includes different skills than mathematics. Based on the taxonomy of Bloom (Bloom, 1956) most of our mathematical skills are in the range of K1-K4, which comprises knowledge-, understanding-, application- and analysis skills. Programming in contrary strongly includes skills based on design and synthesis, which is up to K5 or K6 according to the revised taxonomy of Bloom (Krathwohl, 2002).
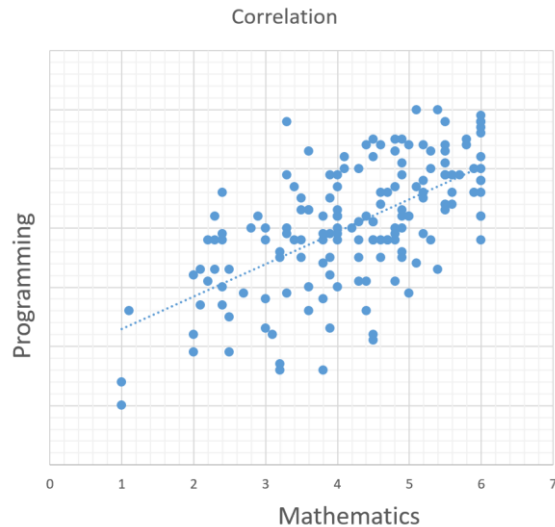
Figure 5: *Correlation of grades in mathematics and programming*

Of course, the background of the students also has some effects on the programming skills. Students that learned programming in an IT apprenticeship definitively have an advantage. However, most foreign students did not have this possibility, since this type of vocational education is not very common in other countries.

3.4 Initial Aptitude Test Results of Applicants and Current Students

As stated previously the test results are not personalized but collected anonymously by allocating participants to the different control groups. Only the participants themselves can see their points related to the four different categories of interest. In order to determine the validity of the test, we collect not only data from the candidates that are interested to start the BIT program, but also from the registered students of the programme. We use the results of our students to get an idea of the minimum target value of the aptitude test, which would be necessary to successfully pass the BIT programme. Our current distribution of the average points show the following results.

distribution of points (external)
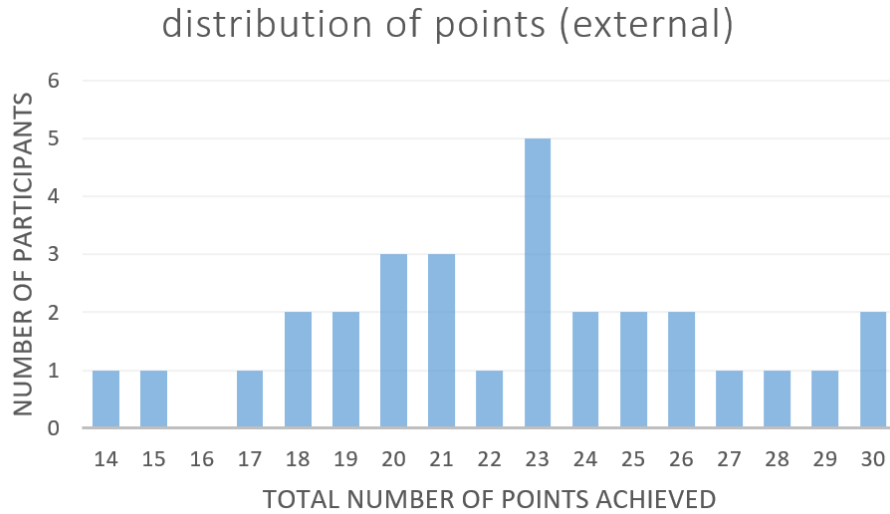
Figure 6: *Distribution of average points of external candidates*

The distribution of figure 6 is based on all the external candidates that did participate in any of our information sessions representing the population of the potential future students. However, it is not clear, which of these will definitely register in our BSc programs.

distribution of points (internal)
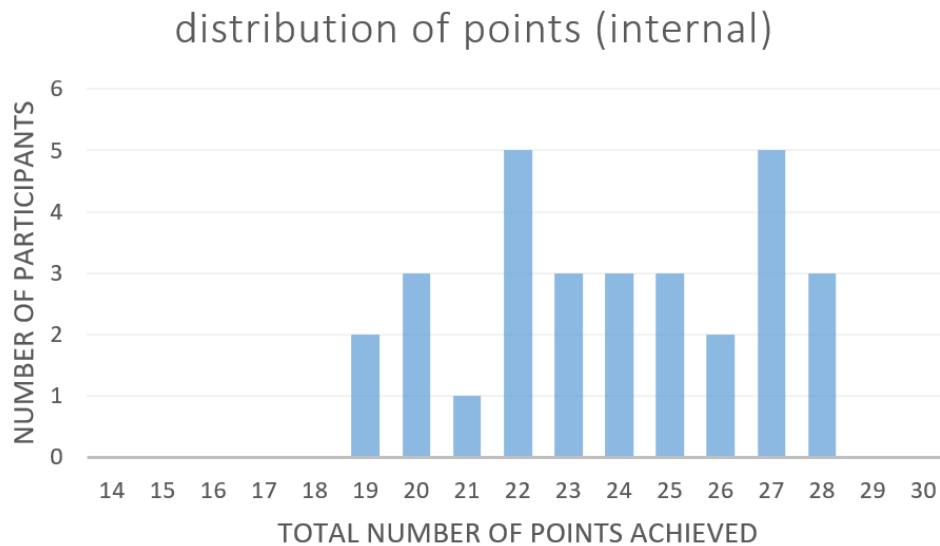
Figure 7: *Average points of internal students*

The distributions of figure 7 looks different. First, the spread is less than the current collection of test results from external candidates. One possible interpretation is that all students that passed the assessment stage have the basic capabilities to reach a level of 18 points or above. On the other hand, it might be that those who really have very good skills in programming and mathematics, finally choose a more technical course of studies, and end up in joining dedicated BSc programmes in computer science.

3.5 Control Group Based Test Results

As one of the initial control groups, the students that failed the assessment stage in 2016 were asked to participate in the aptitude test.
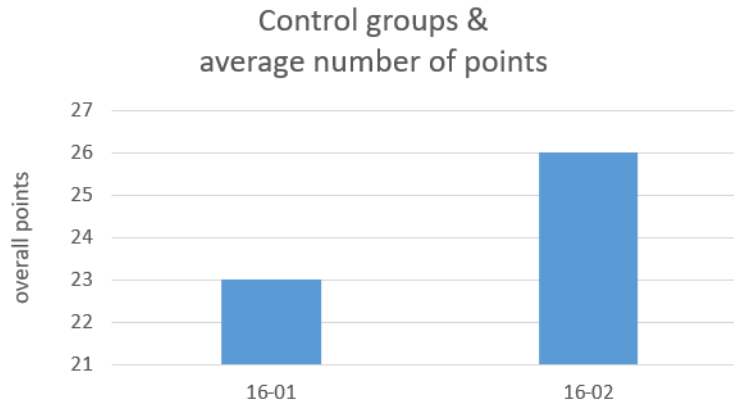
Figure 8: *Average points of internal students*

So far, the control group that failed the assessment stage had 23 points in average, and the group that passed had 26 points, which gives some weak indication on the validity of the test. However, the test population is currently too low to state this as a conclusion for the threshold value.

Another parameter might be the time that students take to finish the test. Some might do it very rapidly; others with more caution investigating more time. The following picture shows the relation of average points and the time of participants needed to complete the test.
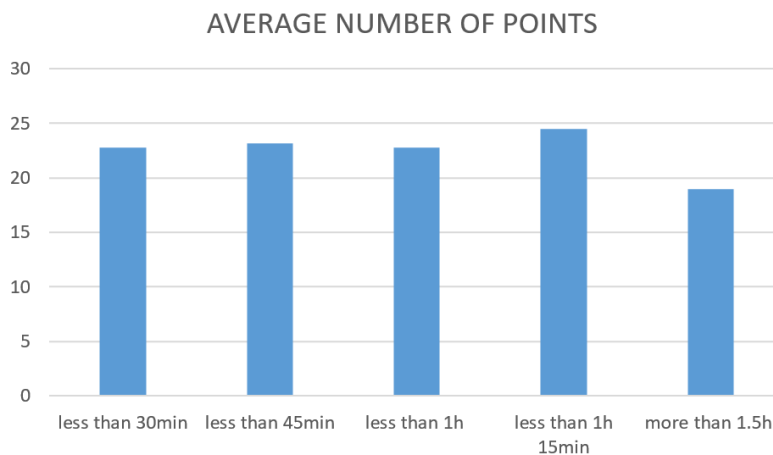

Figure 9: *Average points and time needed to complete the test*

It seems most obvious, that time is not the relevant differentiation factor. More than 40% of the participants had less than 30 minutes; one third had less than 45 minutes. Only one participant spent more than 1.5 hours and got less than 20 points. This could be a possible

indication that it is not the right course of studies. However, the current platform does not provide the feature of automatic time measurements, which would be an important additional requirement for upcoming versions of the test.

In order to determine the validity of the test, our current students were asked to participate in the test as well.
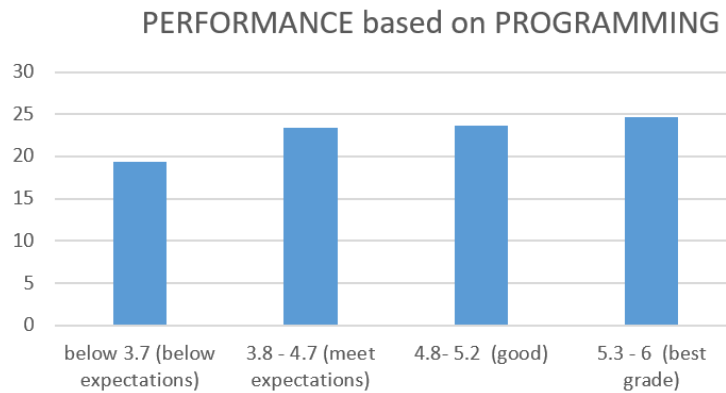
Figure 10: *Average points compared to programming skills*

Figure 10 shows the average points of the student population in the different control groups based on the grades in programming while figure 11 and 12 show the average number of points of all the students, categorized by the different performance bands based on the grades in mathematics and introduction to BIT respectively.
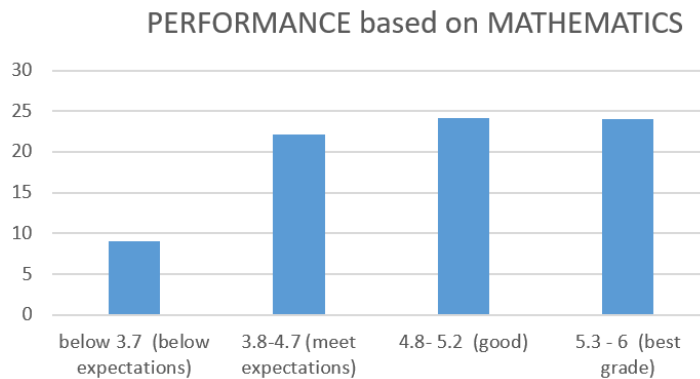
**Figure 11:** *Average points compared to mathematical skills*

PERFORMANCE based on INTRODUCTION BIT
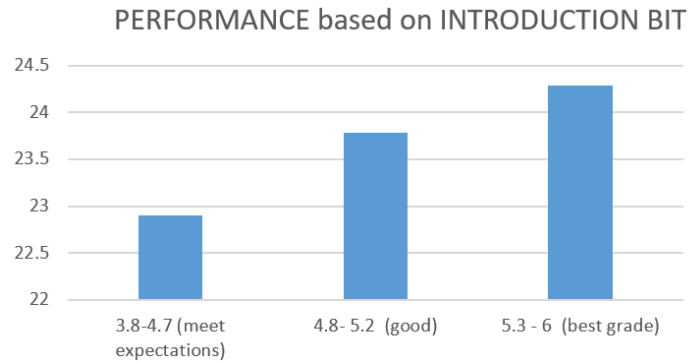
Figure 12: *Average points compared to introduction to BIT course*

Figure 12 show that none of the students that failed in the BIT exam did participate in the self-evaluation test.

Interestingly enough all three comparisons of the average number of points with the average performance in the module exams show a positive correlation. E.g. good performance in the self-evaluation test correlates with good grades in the appropriate modules. Bad performers of mathematics exams got significantly less points in the test.

4. Discussion

Our initial test results provide some evidence that the aptitude test provides some valuable predictive insights in terms of the ability to pass the assessment stage of the BIT program. The evidence of coincidence with the number of points reached in the test and the grades in the modules mathematics and programming is stronger than the correlation of grades from the course introduction to Business Information Technology and the number of points in the evaluation test. However, the number of test results are still too small and some further influencing factors should be taken into account. One major denominator of points achieved in the test might be the different background of the participants. Our course of studies does not require any prerequisite IT knowledge. However, the different background certainly do have some implications. Although figure 13 proves our experience, that our course of studies is manageable for students with and without IT background, especially the work load of students at the beginning is different.
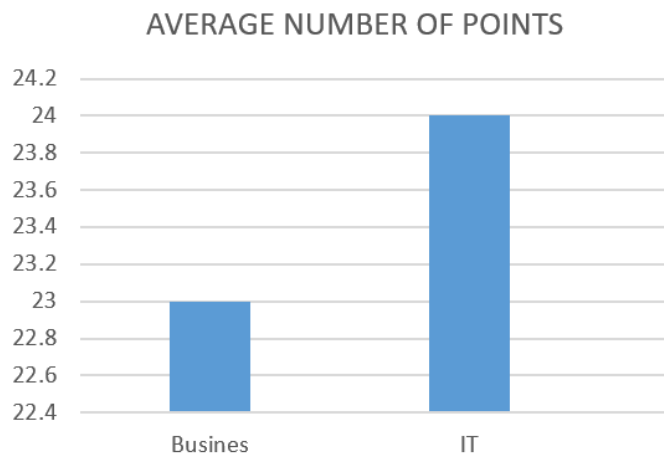
Figure 13: *Average points from students coming from Business or IT background*

Students coming from a business background need to invest substantially more time into the programming course at the beginning, but in the end the results show, that it is also possible to pass the assessment stage with no previous IT experience.

Worth mentioning seems the fact of the difference from the best to the least of the grades (from 6 to 1) in all three courses. Figure 14 shows, that for the best performers, the difference in the grades is less, than the differences for average or low performers in all three courses.
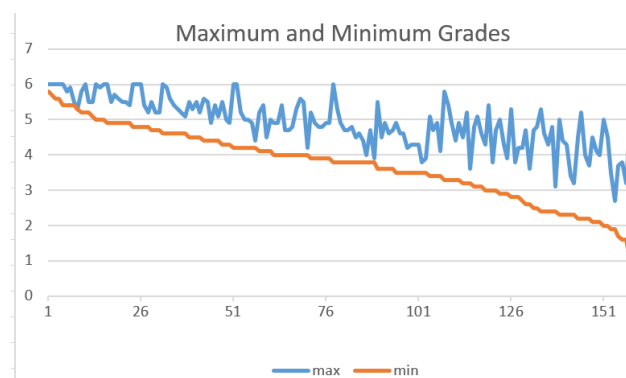
Figure 14: *Correlation of grades in mathematics and programming*

It underlines some qualitative statements from our students that passed successfully the assessment stage. They stated that all students who did continuously do all the exercises in mathematics and in programming did pass the appropriate examinations. Therefore, the grades are highly correlated with the amount of investigation of the students into the subjects. Students showing this attitude are consistently more successful in all modules.

5. Conclusion

The BSc Business Information Technology course of studies is designed for students with an apprenticeship and baccalaureate from the business as well as IT domain and requires a good amount of abstract and logical thinking skills. Students that fail the assessment stage mostly struggle with technical courses such as programming, mathematics or introduction to BIT. Our web-based self-evaluation test is designed for prospective students to get some insight into their personal skills in logical, analytical and abstract thinking. The overall score of the test is based on a total number of points in four different categories. Initial tests are conducted with prospective as well as current students and show some evidence on the validity of the self-evaluation test. The test provides some predictive and valuable insight into the personal ability to master the entire BIT bachelor of sciences course of studies. Although a positive correlation to the test is given, it does not mean, that good test results in the aptitude tests automatically lead to good grades. At most, it serves as an indicator of the necessary abstraction skills as an important prerequisite to pass the assessment stage.

However, the validity of the tests is still limited due to the low number of test results. Retesting with the same participants is not an option. Since the current number of questions is very limited, it is very important the answers for the test questions are not passed along from participant to participant.

The scope of future research includes several dimensions. For the next release of the BIT aptitude test, we plan some improvements, especially in terms of the user interface and the amount of test question in the database, which could be enlarged considerably. One of the major goals of our future research aims to establish the feedback loops between the test and teaching. If it turns out in the aptitude test that prospective students have considerable difficulties to understand some particular concepts or topics in computer science (e.g. inheritance in object orientation, relationships in database modelling etc.), additional exercises could be prepared to particularly address these shortcomings earlier during the semester. Vice versa, those topics that are usually not very well solved in the exams are good candidates for additional test questions. Such incremental adaption of the test questions could further improve the aptitude test and help the students to detect and address their individual shortcomings as early as possible.

Nevertheless, the current test can already give a valuable insight into the kind of skills that are needed to thoroughly follow the course contents and to determine the required abstraction skills that are necessary to do the exercises and pass the exams of the assessment stage.

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