# Title: Providing Every Jack with his Jill – Aiming for Specific Support of Engineering Students in Developing Basic Mathematical Skills

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**Abstract**

*This paper focuses on basic mathematic skills of engineering students as a crucial aspect of their competencies for academic learning (Studierfähigkeit). Based on our expertise in academic teaching, an intervention was devised; low performing students are supported by an additional online course in basic mathematics. This scenario is evaluated with a focusing on the role of individual differences.*

## Introduction

### Theoretical background

Whether university students successfully complete their studies is critically related to how they develop competencies for coping with the kind of teaching-learning scenarios they encounter in the university context. Based on this, we argue that students' competencies for academic learning (German: Studierfähigkeit) develop based on how they perceive and cope with critical incidents during the outset of their academic path (Bosse, Trautwein & Schultes, 2013). For universities to offer specific support in line with the needs of different (sub-groups of students, we need to better understand the moderating role of the individual differences. At the Magdeburg-Stendal University of Applied Sciences (MS-UAS) we have started a project to investigate this question with a focus on the mathematical skills of engineering students.

### Context: Integrated approach to academic development

Funded by the German federal government ("Qualitätspakt Lehre" project) the MS-UAS has founded a center for academic development and applied academic research (ZHH). Based on an integrated framework, the main goal of the center is to orchestrate academic development interventions, organizational development, and empirical research in order to improve academic teaching and study structures at the university (vgl. Merkt, im Druck).
A first study: Basic mathematical skills of engineerign students
For engineering students, basic mathematical skills are an essential competence. However, offers for developing these skills are not necessarily taken up by the students who most need them. In contrast, initial empirical findings show that mostly students who showed satisfactory performance in high school mathematics combined with above-average levels of conscientiousness attend these courses (Krüger-Basener & Rabe, in Druck). An important conclusion that can be drawn from this is that the development of cognitive competencies are closely intertwined with non-cognitive aspects (cf. Trautwein, 2013).

### Design und Research Questions

In a longitudinal, quasi-experimental design we compare students that receive regular mathematics tutoring (*classroom*) in the first semester to a group of students who additionally attend an online-course on basic mathematics (*blended-learning*). Altogether, 60 places were available in the online course. Students were not randomly assigned to the two conditions but selected by two different procedures. First, all students of the tracks mechatronic systems engineering and electrical engineering who scored less than 6 out of 15 points in a mathematics pre-test were obliged to sign in to the online course. The rest of the available places in the online course were distributed among students of the remaining track, mechanical engineering. With this design we are aiming at answering the following two questions:

1. How do students (classroom only vs. blended-learning) differ regarding mathematics performance, motivation and self-concept after one semester?
2. Do individual differences (prior learning experiences, socio-demographic variables, motivation) moderate how students make use of the different learning scenarios?

## Method

### Sample

For the first measurement point 131 first year engineering students completed the questionnaire. There were 56 students who had signed into the online course of which 50% had been obliged to to so. Regarding the evaluation of the online course, only about 40 students completed all questions. We were also able to collect performance data from the online course, however, students were inconstant when providing their anonymous code that only about 25 data sets could be matched.

Regarding the whole sample, the mean age was 23.0 years (*SD* = 4.4) and 88,5% were male. 44,3% of participants were admitted the the university based on their high school graduation (*Abitur* or *Fachabitur*) or an advanced vocational degree (*Meisterprüfung*), 45.8% were admitted based on there regular vocational degrees (*Lehre* or *Facharbeiterabschluss*), 4.6% had already completed another university degree and 5.4% were admitted based on other qualifications. The average mathematics grade of their last school report was 2.7 (*SD* = 1.0, on a scale from 1 = *best* to 6 = *worst*). Most of participants reported that their motivation for choosing an engineering major was either interest in the subject and prior knowledge (72.5%), or the likelihood for finding a good job as an engineer (71%). The three most reported ways of providing for their lives as students were parents/family/partner (38.9%), a federally funded student loan *BAföG* (27.5%), or personal savings/work (16.8%). Half of the were first generation university level students in their family (50.4%), 32.1% had at on parent with a university level education, and 17.6% had two parents with a university degree. Most of the participants were German native speakers (90.8%). Regarding their studies, participants spent on average 22.0 hours (SD = 4.6) per week in class, 9.9 hours (SD = 7.0) studying by themselves, and 5.9 hours (SD = 8.0) working. Prior to the first semester the university had offered a „late summer school" that included a preparatory mathematics course. 40.5% of participants reported to have participated in this course.

### Procedure and measures

The initial plan was to conduct a longitudinal survey covering three measurement points (beginning, middle, and end of first semester). However, due to lack of participation in the first measurement point—which was administered as an online questionnaire—we reverted to a paper-pencil format which was distributed in the introductory mathematics courses for all first semester engineering students for the second and third measurement point.

In addition to the socio-demographic questions that are mentioned in the sample description, we followed the overview over relevant aspects of students' competencies by Trautwein (2013), asked all participants to provide self-ratings on measures of motivation, socio-demographic variables, mathematical self-concept, learning strategies and test performance.

*Perceived autonomy* (adapted from Janke & Dickhäuser, 2013; sample item (reversed): *In my studies I often feel I have to do what I am told.*) and perceived *social inclusion* (adapted from an unpublished questionnaire of the Harz University of Applied Sciences, sample item: *I maintain close relationships to the fellow students from my track.*) Unfortunately, both scales did not show sufficient internal consistency, Cronbach's $\alpha \leq .43$—possibly due to the different organization of the different tracks—so the single items will be analyzed when the final measurement point ist completed in the future.

The students' *mathematical self-concept* was assessed by four items (adapted from Marsh, 1992; sample item: *I have always been proficient in mathematics.*) that were rated on a 4-point-Likert scale (1 = *completely disagree* to 4 = *completely agree*). Internal consistency was satisfactory, Cronbach's $\alpha = .76$. To assess students *self-regulatory skills* they rated eight items on the same 4-point Likert scale (adapted from Schwarzer, 1999; sample item: *I can concentrate on one thing when it is necessary.*). This scale also was sufficiently reliable, Cronbach's $\alpha = .74$. Students also rated their *general satisfaction* (on item) on a 4-point Likert scale (1 = *completely dissatisfied* to 4 = *completely satisfied*). Furthermore they indicated their perceived *congruency* between their study-related expectancies and their actual study experience (5-point Likert scale, 1 = *not at all* to 5 *very much*), as well as how they rated *adequacy of the levels of performance* that were demanded in their studies, and the *amount of material* to be studied each on a 5-point Likert scale (1 = *too low* to 5 = *too high*).

Regarding the evaluation of the mathematics online course, the respective sub-sample of students was asked to note how regularly they had made use of the different offers of the online course (study units, training and daily tasks, contact with a course mentor, reflecting on mentor's feedback) on a 5-point Likert scale (1 = *never* to 5 = *very often / always*). Similarly, students rated the usefulness of the online course on three items (sample item: *The online course has helped me to recapitulate my mathematical knowledge.)* using a 4-point-Likert scale (1 = *completely disagree* to 4 = *completely agree).* Exploratory factor analysis revealed that these items loaded on one factor and were therefore averaged as an indicator of usefulness, Cronbach's $\alpha = .78$.

## Findings

### General findings

Findings reported here are only based on the second measurement point (middle of semester). The first important finding was, that students overall performed very poorly on the mathematics pre-test that was conducted in order to select students for the online course ($M$ = 3.09, $SD$ = 2.75). Further, students reported an average self-concept regarding their mathematical skills and above average self-regulatory skills. Students reported clearly above-average satisfaction with their studies and above average congruency between their expectations and study reality. Similarly, students deemed the demanded level of performance and the amount of study material as rather adequate. For descriptive statistics see Table 1.

Table 1. Means (*M*) and Standard Deviations (*SD*) of student characteristics.

| | *M* | *SD* | α |
|---|---|---|---|
| Mathematics pre-test | 3.09 | 2.75 | - |
| Mathematical self-concept | 2.28 | 0.28 | .76 |
| Self-regulatory skills | 2.75 | 0.29 | .74 |
| Overall satisfaction with studies | 3.25 | 0.57 | - |
| Congruency between expectations and study reality | 3.73 | 0.60 | - |
| Adequacy of demanded level of performance | 3.50 | 0.59 | - |
| Adequacy of amount of study material | 3.62 | 0.63 | - |

**Evaluation of online course**

The students who participated in the online course reported that the offers they had taken up most where the possibility to contact and ask the online mentor, the online learning units, and completing the daily tasks. The overall helpfulness of the course was considered only slightly above average. For descriptive statistics see Table 2.

Table 2. Means (*M*) and Standard Deviations (*SD*) of students' evaluation of the online course.

| | *M* | *SD* | α |
|---|---|---|---|
| Online learning units[a] | 3.48 | 1.11 | - |
| Online training tasks[a] | 1.69 | 1.10 | - |
| Online daily tasks[a] | 3.38 | 1.48 | - |
| Contact with online course mentor[a] | 3.56 | 1.50 | - |
| Reflect on mentor's feedback[a] | 2.75 | 1.37 | - |
| Overall helpfulness[b] | 2.86 | 1.90 | .78 |

*Note.* $^{a}N = 54$, $^{b}N = 43$.

**Group comparisons**

We then also compared the two conditions (classroom vs. blended-learning) with regard to socio-demographic variables and other student characteristics at this point of the study. Because we know that 56 students had signed in to the online course, we used the sub-sample of $n = 54$, who had reported on the frequency of their online course attendance to identify the students in blended learning condition. The final measurement will include a validation question so we will be able to clearly identify these students.

Chi-square tests showed not significant differences regarding socio-demographic variables, or students' motivation to study, *p*s ≥ .27. However, regarding the students participation in the late summer school, there were significantly less students in the blended-learning condition that had also attended the summer school, $\chi^2(1, N = 131) = 4.47$, $p = .03$. See Table 3 for numbers of students.

Table 3. Number of students in each condition who also attended the late summer school.

| Attendance late summer school | Participation online course | |
|---|---|---|
| | no (classroom condition) | yes (blended-learning condition) |
| no | $n = 40$ | $n = 38$ |
| yes | $n = 37$ | $\boldsymbol{n = 16}$ |

Independent sample *t*-tests showed that the students in the two conditions also did not differ regarding all assessed variables, *p*s ≥ .13. The only marginally significant effect was that students who had participated in the online course reported to be more satisfied with their studies ($M = 3.35$, $SD = 0.62$) than those who did not participate ($M = 3.17$, $SD = 0.53$), $t(128) = -1.79$, p = .08.

## Discussion

Our study aims at providing empirical basis for more evidence-based design of measures that help engineering students to master the transition from their prior learning settings (high school or working life) into the setting of applied university studies. The main focus of our study is to test how an add-on online-course on basic mathematics can work as one such measure for supporting students.

Regarding the experimental vs. control group design of our study, the results showed that we managed to create two comparable groups considering socio-demographic and learning related variables. Interesting are the findings regarding another measure to support students' entry phase into university. The mathematics course in a preparatory late summer school was associated with a lower number of these students who were also selected for the online course. One possible interpretation is, that indeed the late summer school helped students to improve their mathematical skills. Follow-up analysis also showed that students who participated in the late summer school but were not selected for the online course showed marginally better results in the mathematics pre-test, $F(1, 105) = 3.52$, $p = .06$. However, we do not know whether this group of students did not enter the late summer school with better skills. What we can say is that they do not differ with regard to their mathematical self-concept, *F*s < 1, which indicates that there is no easy differences-in-motivation explanation. In sum, we take away from the analysis of the first measurement that it seems worthwhile to consider the four groups of students that differ regarding (non-)participation in the two support activities (online course and late summer school, respectively).

### Practical implications

Although we cannot conclude final implications at this point of the study, we think it is important to share some hypothesis and questions that arose from the preliminary analysis. One important finding was that that students' performance in the mathematics pre-test was generally low. Looking at the scores of mean plus/minus one standard deviation, we can see that 68.27% of the students were remained below the cut-off criterion (6 out of 15 points) that was set by the responsible teachers prior to our findings. We think that this shows that mathematics skills are generally lower in all students than they are expected to be by university teachers. This finding implicates that there is a mismatch between the university's expectation regarding the mathematic skills (and maybe other skills as well, such as text comprehension?) of first year students and the empirically found low performances. Instead of supposing individual problems of a small group of students as has been the usual presupposition until now the University faces a structural problem with obvious consequences for curricular changes. The expected mathematic skills are basic for the planned progression within the engineering study program. Given the fact that financial shortcuts for all Universities have been announced for the federal state of Sachsen-Anhalt it will be challenging to convince academic teachers of respective necessary curricular changes. Regarding further interpretations of data it will be one question to explore if the investigated settings (late summer school and additional online-course) show significant differences in enhancing the mathematic skills of the participating students.

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