Different goals for pre-university mathematical bridging courses – Comparative evaluations, instruments and selected results

Biehler Rolf, Elisa Lankeit, Silke Neuhaus

Different goals for pre-university mathematical bridging courses – Comparative evaluations, instruments and selected results

[1]Rolf Biehler, [1]Elisa Lankeit, [1]Silke Neuhaus, [2]Reinhard Hochmuth, [2]Christiane Kuklinski, [2]Elena Leis, [2]Michael Liebendörfer, [1]Niclas Schaper, and [1]Mirko Schürmann

[1]University of Paderborn, Germany; biehler@math.upb.de, elankeit@math.upb.de, nsilke@math.upb.de, [2]University of Hannover, Germany.

To ease difficulties in the transition from school to university, bridging courses are implemented at many German universities. In this paper, we present instruments we have developed for evaluating those bridging courses. We also show selected results from six bridging courses at five German universities, comparing their different goals and achievements.

Keywords: mathematical bridging courses, instruments for evaluation, transition to and across university mathematics, teachers' and students' practices at university level

INTRODUCTION

The transition from school to university is a big challenge for many students, especially in mathematics (Biehler, Hochmuth, Fischer, & Wassong, 2011; Gueudet, 2008). Several supportive measures such as pre-university bridging courses or mathematical support centres are implemented at German universities to ease students' difficulties in the transition phase (Hoppenbrock, Biehler, Hochmuth, & Rück, 2016). But we often do not know how effective these supportive measures are as detailed studies on the effects and success conditions are missing.

THE WIGEMATH-PROJECT

At this point, the ongoing WiGeMath project (Effects and success conditions of mathematics learning support in the introductory study phase), a joint project of the universities of Hannover and Paderborn (Liebendörfer et al., 2017) in collaboration with 14 universities, comes in. We distinguish four types of support: pre-university bridging courses, mathematics support centres, newly designed bridging lectures in the first semester, and support systems accompanying traditional lectures such as e-learning material or extra tutorials. The WiGeMath project's goals are developing a theoretical framework in order to be able to describe, analyse and compare support measures, investigating effects and success conditions and elaborating recommendations for effective designs for mathematical support measures in the introductory study phase. The theoretical framework for the examinations is the 3P model of Thumser-Dauth (2007). It describes a programme evaluation for higher education measures based on Chen's theory-driven evaluation approach (Chen, 1990). Based on transition literature from mathematics education, we refined this framework to

make it content-specific. Interviews with our collaborating universities and document analysis were used to locate the specific measures in the framework (Liebendörfer et al., 2017). The reconstructed programme theories contain goals, procedures, circumstances and expected effects of the measures. Based on the theoretical framework, instruments were developed for evaluating the success of the measures.

Bridging courses in Germany

Most German universities provide bridging courses in mathematics for various kinds of beginning students shortly before the first semester. They differ in length, structure, amount of e-learning, content, audience, and goals. Some courses focus on the repetition of school mathematics while others aim at introducing students to university mathematics content and working methods (Bausch et al., 2014; Biehler & Hochmuth, 2017).

One main aim is to evaluate the success of bridging courses by assessing short term and medium term effects on attitudes and mathematical knowledge of the students. Therefore, we questioned the students at the beginning of the course, immediately after the course and after two months in the first semester.

Sample: Selected Bridging courses in the WiGeMath study

The following six bridging courses at five German universities are included in the analysis.

University	**Online (O) or Attendance (A)**	**Duration in weeks**	**Aimed at…**
A	O	5	Math., Comp. Sci., Engineering, teacher ed.
B	A	2	Engineering
C	A	2	Math., Physics, teacher ed.
D_A	A	4	Math., Comp. Sci., teacher ed.
D_O	O	4	All math programs (except econ. and physics)
E	A	2	Math., teacher ed.

Table 1: Overview over the investigated bridging courses

RESEARCH QUESTIONS

In this paper, we will focus on the post-test directly after the course. Apart from evaluating different instruments used in the post-test questionnaire the research questions are:

1. Which goals do lecturers of bridging courses set for their courses? How can the profiles of the courses be compared and located in the WiGEMath framework?
2. To which extend do students think they achieved explicit or implicit goals of their bridging course?
3. How much do the results of two different instruments measuring to which extend the students think they achieved different goals in the bridging course differ?
4. How do the (theoretical) profiles set up by the lecturer differ from the empirical profiles of the course?

METHODS AND INSTRUMENTS FOR EVALUATING BRIDGING COURSES

Instruments based on the WiGeMath Framework

The 13-pages questionnaire for the post-test contains about 205 Items – usually 6-level Likert-scale from "strongly agree" to "strongly disagree". The following tables illustrate the scales with exemplary items. Most of our scales had a reliability above 0.6 in the majority of cases at all locations.

Category of goals	**Scale name**	**Example item**
School math. knowledge and competencies	Identifying and overcoming deficiencies in school mathematics.	"I got to know my individual deficiencies in school mathematics."
	Recapitulating and elaborating school mathematics	"School mathematical topics were repeated."
University math. knowledge and competencies	University mathematics knowledge and competencies	"I learned new mathematical topics."
Mathematical terminology	Mathematical terminology	"I have learned new mathematical symbols"

Table 2.1 Knowledge goals

Category of goals	**Scale name**	**Example item (of 2 to 4 per scale)**
Mathematical modes of working	Process-related competences concerning math. texts	"I have learned how to read mathematical texts."
	Metaknowl. for math. modes of working	"I know how to recapitulate a mathe-

		matical lecture.”
	Working autonomously on math. tasks	“I can work on mathematical tasks and topics on my own for some hours. “
University modes of working (*)	Organizing university routine	“I learned how to organise my daily routine at university on my own.”
Learning strategies (*)	New ways for learning mathematics	“I learned about new ways to study mathematics.”
Learning and working behaviour	Study groups (*)	“I learned to work in study groups.”
	Knowledge about digital tools and how to use them	“I know the digital learning platforms used at my university.”

Table 2.2 Behavioural (action-oriented) goals. (*) only one item

Category of goals	**Scale name**	**Example item (of 3 to 7 per scale)**
Beliefs	Metaknowl. and beliefs concerning higher maths.	“In the course, I recognised the role of proofs in higher mathematics.”
Relevance of school maths. for future studies	Estimating how relevant school mathematics are for future studies and later profession	“In the course, I became aware that school mathematics provides a basis for my further studies.”

Table 2.3 Attitudinal goals

Category of goals	**Scale name**	**Example item (of 2 to 6 per scale)**
Social contacts	Social contacts between students	“I met fellow students.“
	Perceived social integration (Rakoczy, Buff, & Lipowsky, 2005)	“I think the other students of the course would help me, if necessary.”
	Studying together with fellow students (Liebendörfer et al., 2014)	“If I have an idea for a solution, I will discuss it with other students.”
Making uni-	Gaining insight into university	“I gained insight into higher

versity study demands transparent	learning/teaching methods regarding mathematics	mathematics learning and teaching methods at university.”
	Getting to know possible difficulties at the beginning of university and how to solve them	“I heard about possible difficulties at the beginning of my studies.”

Table 2.4 System-related goals

Additionally, we asked the participants about some affective characteristics (such as mathematical fear and self-regulation), these items are not used in the analysis for this paper.

Instruments adapted to the explicit goals of the course

The WiGeMath instruments are based on a comprehensive framework of potential goals of a bridging course. As a supplement we used a learning outcome oriented evaluation system, called BiLOE, proposed by Frank and Kaduk (2015). For the BiLOE, each lecturer is asked to specify her/his three to six major learning goals in his/her own words. Additionally, the lecturers had to specify up to seven study activities that should help the students to achieve these goals. Students are asked to evaluate these goals and activities. An important further element of the BiLOE is that the students have to state their personal goals for the course and are asked to which extend they think they achieved them. Those students who did not believe they achieved a learning goal were asked to give reasons for this at the end of the questionnaire. The BiLOE also requests the students to evaluate the relevance of the lecturer’s goals and how much certain activities helped them to achieve those goals.

SELECTED RESULTS

RQ 1: The different profiles of the investigated bridging courses

We categorized the major goals provided by the lecturers in the BiLOE from the perspective of the WiGeMath framework. The results can be found in table 3. Quite different profiles become visible.

Category	**A**	**B**	**C**	**D_A**	**D_O**	**E**
School math. knowledge and competencies	1	1	0	0	1	0
University math. knowledge and competen-	1	1	1	1	1	3
Mathematical terminology	1	0	0	0	0	1
Mathematical modes of working	0	0	0	0	0	2
University modes of working	0	0	1	0	1	0
Learning strategies	0	0	0	0	0	0
Learning and working behaviour	0	2	1	0	2	0
Social contacts	1	0	0	1	0	0

Making university demands transparent	0	0	0	2	0	0

Table 3: Number of learning objectives in the respective category mentioned by the lecturers

It is striking that no attitudinal goals were mentioned among the major goals, neither beliefs, nor affective features, nor mathematical enculturation. Likewise, none of the lecturers mentioned teaching learning strategies as a goal of their bridging course.

RQ 2: Goal achievements

The results of the WiGeMath and the BiLOE instruments provide valuable information for every single lecturer. The broader spectrum of the WiGeMath results will moreover provide information on the effects of the course from the perspective of its participants that the course lecturer may not have explicitly thought of in the selected major goals. This analysis provides empirical profiles and assesses the success of the various bridging courses.

In all cases, we calculated the percentage of students who *rather agree* up to *fully agree* (meaning greater than 3 in Likert scales with 4 steps or greater than 4 in Likert scales with 6 steps, respectively).

The following tables show the percentage of participants agreeing to the WiGeMath scales concerning the respective categories.

Category of goals / Scale	**A**	**B**	**C**	**D_A**	**D_O**	**E**
School math. knowledge and competencies						
Identifying and overcoming deficiencies in school math.	59	81	58	33	71	34
Recapitulating and elaborating school math.	86	89	69	34	87	35
University math. knowledge and competencies						
University mathematics knowledge and competencies	60	89	100	95	73	95
Mathematical terminology						
Math. terminology	63	86	99	97	74	96

Table 4: Results knowledge goals: Rounded percentage of participants agreeing to the WiGeMath scales (n=651)

Category of goals / Scale	**A**	**B**	**C**	**D_A**	**D_O**	**E**
Mathematical modes of working						
Process-related competences regarding math. texts	36	42	74	46	31	56
Meta knowledge for mathematical modes of working	34	72	70	66	46	65
Working autonomously on mathematical tasks	70	73	76	65	64	71

University modes of working						
Organizing university routine	45	58	42	41	46	49
Learning strategies						
New ways for learning mathematics	55	58	74	51	44	69
Learning and working behaviour						
Study groups	25	49	88	47	17	82
Knowledge about digital tools and how to use them	58	80	54	67	77	45

Table 5: Results action-related goals: Rounded percentage of participants agreeing to the WiGeMath scales (n=651)

Category of goals / Scale	**A**	**B**	**C**	**D_A**	**D_O**	**E**
Beliefs						
Meta knowledge and beliefs towards higher mathematics	50	70	94	90	59	90
Relevance for eventual profession and for subsequent studies						
Estimating how relevant school mathematic is for university and profession	63	74	63	54	71	44

Table 6: Results attitudinal goals: Rounded percentage of participants agreeing to the WiGeMath scales (n=651)

Category of goals / Scale	**A**	**B**	**C**	**D_A**	**D_O**	**E**
Social contacts						
Social contacts between students	34	84	98	76	64	86
Perceived social integration	46	82	93	88	74	89
Studying together with fellow students	36	71	81	66	57	88
Making university demands transparent						
Gaining insight in university learning/ teaching methods regarding mathematics	34	82	95	85	44	91
Getting to know possible difficulties at the beginning of university and how to solve them	31	67	81	42	62	63

Table 7: Results system-related goals: Rounded percentage of participants agreeing to the WiGeMath scales (n=651)

RQ 3: Differences between the two evaluation tools

To compare BiLOE and WiGeMath data, we first matched the learning goals given by the lecturers with the framework categories. The BiLOE results are mostly similar to the WiGeMath results. There are only six cases with differences of more than 15

percentage points. We reported back the interesting differences to the respective lecturers but these are relevant only for the individual and provide the general insight that the WiGeMath framework is sufficient for the evaluation.

RQ 4: Comparison of theoretical and empirical profiles

With these empirical results, a re-evaluation of the profiles based on the formulated learning goals of the respective bridging courses is possible. We will evaluate in which categories the percentage of agreeing participants are high or low and compare these results to the theoretical profiles. Here, "high" means an agreement to the WiGeMath scales of more than 80% of the participants and "low" is an agreement of less than 40%.

Course A. Based on the formulated learning goals, bridging course A has many goals. School mathematics, university mathematics, mathematical modes of operation, and social contacts are aimed at equally strongly. The empirical results differ: The only category with high agreement is school mathematics. There are some categories with low agreement, including social contacts, which was originally formulated as a goal by the lecturer.

Course B. Goals in various categories were stated as well. The empirical profile is similar but even broader: high agreement is reached in school mathematics, university mathematics, mathematical terminology, social contacts, and gaining insight in university learning and teaching methods. No goals concerning the last three categories were stated by the lecturer.

Course C formulated various goals. The empirical results show that there is high agreement in the categories university mathematics and study groups. There is also high agreement in the categories mathematical terminology, meta knowledge and beliefs towards high mathematics, social contacts and making university demands transparent.

Course D_A's empirical results also fit the theoretical classification very well. Additionally, high agreement is reached for mathematical terminology and meta knowledge and beliefs towards high mathematics. The only category with a low percentage is school mathematics, which was not an explicit learning goal, however.

Course D_O. The empirical profile of this bridging course differs significantly from the profile based on learning goals. The only category with a high percentage of agreement is school mathematics. Therefore, the focus of the course seems to be more on school mathematics than on university mathematics. Based on the learning goals, both could have been seen as equally strong.

Course E was the only one with a clear profile based on the formulated learning goals which was on university mathematics (including mathematical terminology). This is reflected in the empirical results, which however show a broader spectrum. Additionally, there is also a high percentage in the categories studying in study

groups, meta knowledge and beliefs towards high mathematics, social contacts, and gaining insight in university learning and teaching methods. Low agreement was found concerning school mathematics, which was not a formulated learning goal.

SUMMARY AND DISCUSSION

The presented results are an intermediate step in communicating back to those who were responsible for the respective bridging courses with two goals. The immediate goal is to give feedback in order to improve and change the profile of the course – if desired. The second goal is to redesign our instruments so that the future instrument combines scales from the WiGeMath framework and more specific goals of the lecturers. The lecturers' goals given are quite diverse but all goals could be classified into the theoretical framework of the WiGeMath project. Some WiGeMath categories remained empty, however, e. g. learning strategies. We asked for the most important 5 goals, so it may be the case that our lecturers regarded them as minor ones. Additionally, some lecturers stated more specific goals, while other stated general ones. This may be due to the lack of experience with formulating learning goals as most of the lecturers do not work in the field of didactics. It seems necessary and valuable to extend the phase of specifying BiLOE goals by informing the lecturer in more depth about the WiGeMath framework as a supportive frame for specifying their own goals.

The students in the different courses differ when referring to their achievement of certain goals and categories. This is no surprise. For example, an online bridging course will not provide as much social contact to other students as an attendance based bridging course. It is important to mention that all answers are based on the students' self-assessment. The instruments developed (termed WiGeMath scales) and the BiLOE mostly yield similar results, sometimes the results differ. That can be explained by the BiLOE items being more specific or some of the learning goals only having a corresponding category but no perfectly fitting scale was found, as the questionnaire was already up to 13 pages long. The BiLOE is limited by the number of goals a lecturer can state, while the developed instruments of the WiGeMath projects allow providing a general survey of the bridging course. Additionally, the (theoretical) profiles set up by the lecturer differ from the empirical profiles of the course. For example, no lecturer mentioned an attitudinal goal. Nevertheless, the WiGeMath scales show that there is very high agreement in this category in relation to courses for students in mathematics and mathematics teacher education. In these courses the focus explicitly lies on university mathematics and not on the recapitulation of school mathematics.

ACKNOWLEDGEMENTS

The WiGeMath project is supported by the German Federal Minister for Science and Research (BMBF) (FKZ 01PB14015B and 01PB14015A).

REFERENCES

Bausch, I., Biehler, R., Bruder, R., Fischer, P. R., Hochmuth, R., Koepf, W., Schreiber, S., Wassong, T. (2014). *Mathematische Vor- und Brückenkurse. Konzepte, Probleme und Perspektiven.* Wiesbaden: Springer Spektrum.

Biehler, R., & Hochmuth, R. (2017). Relating different mathematical praxeologies as a challenge for designing mathematical content for bridging courses. In R. Göller, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Didactics of Mathematics in Higher Education as a Scientific Discipline – Conference Proceedings* (pp. 14-20). Kassel: Universitätsbibliothek Kassel.

Biehler, R., Hochmuth, R., Fischer, P. R., & Wassong, T. (2011). *Transition von Schule zu Hochschule in der Mathematik: Probleme und Lösungsansätze* Münster: WTM-Verlag.

Chen, H.-T. (1990). *Theory-driven evaluations*. Newbury Park: SAGE Publications.

Frank, A., & Kaduk, S. (2015). Lehrveranstaltungsevaluation als Ausgangspunkt für Reflexion und Veränderung. Teaching Analysis Poll (TAP) und Bielefelder Lernzielorientierte Evaluation (BiLOE). *QM-Systeme in Entwicklung: Change (or) Management?*, 39.

Gueudet, G. (2008). Investigating the secondary–tertiary transition. *Educational studies in mathematics, 67*(3), 237-254.

Hoppenbrock, A., Biehler, R., Hochmuth, R., & Rück, H.-G. (2016). *Lehren und Lernen von Mathematik in der Studieneingangsphase*. Wiesbaden: Springer Spektrum.

Liebendörfer, M., Hochmuth, R., Biehler, R., Schaper, N., Kuklinski, C., Khellaf, S., .Colberg, C., Scürmann, M. , Rothe, L. (2017). A framework for goal dimensions of mathematics learning support in universities. In T. Dooley & G. Guedet (Eds.), *Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education (CERME10, February 1 – 5, 2017)* (pp. 2177-2184). Dublin, Ireland: DCU Institute of Education and ERME.

Liebendörfer, M., Hochmuth, R., Schreiber, S., Göller, R., Kolter, J., Biehler, R., . . . Ostsieker, L. (2014). Vorstellung eines Fragebogens zur Erfassung von Lernstrategien in mathematikhaltigen Studiengängen. In J. Roth & J. Ames (Eds.), *Beiträge zum Mathematikunterricht 2014* (Vol. 1, pp. 739-742). Münster: WTM-Verlag.

Rakoczy, K., Buff, A., & Lipowsky, F. (2005). *Dokumentation der Erhebungs- und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie. "Unterrichtsqualität, Lernverhalten und mathematisches Verständnis", 1. Befragungsinstrumente*. Frankfurt, Main: GFPF u. a.

Thumser-Dauth, K. (2007). *Evaluation hochschuldidaktischer Weiterbildung: Entwicklung, Bewertung und Umsetzung des 3P-Modells*. Hamburg: Kovač.