Teaching Quantitative Exercise Courses (1)

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Instructional Strategies

Overview

1. Working on the board and the “Kreuzerl” (Checkmark) exercise

Having students solve problems on the board is a traditional approach in math exercises. The so-called “*Kreuzerl-Übung*” (“Checkmark” on Moodle) model as a digital alternative is commonly used. On a list of homework problems, students indicate the ones they have worked out at home and are prepared to present on the board before the class.[1]

When students explain a solved problem to peers, they **deepen** their **understanding** of the subject matter.[2] A successful board presentation can also enhance students’ **self-efficacy** and **communication skills**. As instructor, you **monitor** each step of your students’ problem solving process and provide immediate and necessary **feedback**. However, working on the board may be

stressful for some students (e.g. because they are afraid of making a fool of themselves, or out of fear of speaking in front of the class) and, thus, negatively impact student learning. You can use other teaching strategies (see below) to support anxious students or students who suffer math anxiety.[3]

If you notice that your students fail to solve the problems at home, you can use class time for **learning opportunities** that go beyond the presentation of solutions.

2. Learning from model solutions

The well-established approach of working with model solutions can be very effective if your students merely copy solutions from books or from peers, without learning how to methodically arrive at solutions.[4] This strategy **provides the problems as well as the solutions**, allowing the possibility to reconstruct and practise the logic at arriving at the answers in each exercise. It works particularly well for conveying basic knowledge. Here are some variations of how to design learning from model solutions:

- **Master-apprentice model (cognitive apprenticeship)**:[5] Teachers solve problems and explain each step in detail. Students then gradually solve examples on their own. If you use this approach, make sure to allow ample time to discuss problem solving procedures in detail. Moreover, it is crucial to illustrate a topic/concept by using several different examples. Students need to understand the underlying structures and principles and not imitate a single path to a solution without truly understanding.[6]
  Explaining all the necessary steps to solving a problem can be a challenge for teachers, especially when the students are inexperienced. Small details that seem obvious to experts, and are thus not addressed and explained, can hinder student understanding. Creating an open atmosphere in which students may always ask questions and feel comfortable to do so can help avoid this difficulty.
- **Discussions**, also in **small groups**, are an interactive version of learning based from model solutions. To help them understand the quantitative concepts, students practise solving model problems prior to class meetings, trying to understand and reproduce solutions. In class, they explain and discuss model solutions in small groups, thus learning from one another.
  Group composition may depend on various factors, including the objectives you set for the group work. When students with **different knowledge levels** work together, the more advanced students can support the weaker ones and learn from actively explaining concepts and how to solve the problems. On the other hand, students in groups with **similar knowledge levels** can challenge each other and perhaps make more progress.
  Please note: Three to five students is often a recommended ideal **group size.** In math and the natural sciences, research suggests that groups of three work well for problems that that have multiple paths to a solution. However, groups should be larger if the task is to brainstorm or to interpret, i.e. when more perspectives promise better or more creative results.[7]

  Students also benefit from working together in small groups outside of class. Such gatherings can influence how successfully students perform overall, especially in STEM disciplines. Groups formed in class sometimes stay together well beyond the duration of the course. This is especially beneficial for shy students who become part of a peer (study) group without having to actively initiate or join one themselves.

3. Problem-based learning

Problem-based learning (PBL) can be a useful teaching strategy when students have problems understanding the connections between **theory and practice** or grasping the **applicability** of what they learn. In PBL, students work in **teams** to solve **real-world problems** independently, while the teacher remains in the background available for support when necessary. Problem-based learning requires a certain level of basic knowledge. In addition, the method is **challenging** because students have to interpret and understand a problem, work out possible solutions, choose the best one, as well as interpret, critically evaluate, and present results. However, instructors who have used PBL have reported that the work pays off. Students experience cooperative learning and problem solving in a small group as very helpful; the connection between conceptual knowledge and application becomes clear, and thus the relevance of the course content.[8]

4. Using digital media

Digital media inside and beyond the classroom opens up additional learning opportunities (blended learning). For students new to the university, or groups with different knowledge levels, using digital media can help students **fill in** knowledge gaps, e.g. through videos, exercises or self-tests on Moodle.[9]

- **Just-in-time teaching (JiTT)** is a version of blended learning. Students complete online assignments before class that inform teachers about what they know and where they still have problems. Instructors then adjust their teaching based on this information.[10]
  If instructors use class time for exercises, they can use JiTT to check in advance whether students have the necessary **basic knowledge** or **conceptual understanding** to participate in in-class activities.[11] **Warmups** and **puzzles** are further options. Warmups are simple questions get ready for an upcoming topic, which enable deeper and more sophisticated work during class. Puzzles, on the other hand, conclude a topic, or synthesise various topics. Typically, these puzzle assignments are typically more complex than warmups, and may include previously discussed content.[12]

  Please note: Make sure you **schedule** these pre-class activities **realistically**, so that you can react to the information on student learning in the following class session.
- **Flipped classroom**: Flipped classroom is also a variant of blended learning in which the traditional input from teachers in class is replaced by content conveyed through digital media that students work on outside of class (e.g. videos that are made available on Moodle). This leaves more class time for other learning activities (see Flipped Classroom (https://infopool.univie.ac.at/en/home-page/teaching-advising/flipped-classroom/)).
  Even though teachers use this approach mainly in large classes (lectures), some of its elements can also enrich exercise courses. If, for example, you usually start your class with a short review of previous lecture, you could replace this step with a video that your students view before coming to class (possibly supplemented with questions on Moodle).
- Audience Response Systems (ARS) such as ARSnova (https://arsnova.univie.ac.at/mobile/) are suitable for in-class use to quickly get a sense of your students' learning progress (e.g. in the form of quizzes, surveys, short answer questions, etc.) In addition, ARS may prove useful to collect questions or feedback from students.
- In the past several years, **learning paths** have proven to be an effective digital learning support for quantitative exercise courses. Learning paths consist of series of topics and assignments made available online (e.g. Moodle) that students work through independently.[13] Teacher have a range of different options on how to design such learning paths. A number of learning paths that cover many fundamentals are available online:
  - http://www.juergen-roth.de/lernpfade/ (http://www.juergen-roth.de/lernpfade/)(in German)
  - For the university context see: https://www.mathe-online.at/lernpfade/liste.cgi?subj=uni (https://www.mathe-online.at/lernpfade/liste.cgi?subj=uni) (in German)

Continue reading

Teaching Quantitative Exercise Courses (2): Feedback and Assessment (https://infopool.univie.ac.at/en/home-page/course-types-disciplines/teaching-quantitative-exercise-courses/2-feedback-assessment/)

References

[1] You can create and administer this list on Moodle. For assistance, please consult the cheat sheets on „Checkmark": https://www.academic-moodle-cooperation.org/en/documentation/cheat-sheets-en/ [03.02.2021].

[2] Cox, Bill, and Michael Grove. *Teaching Mathematics – A Guide for Postgraduates and Teaching Assistants*. The Maths, Stats & OR Network, 2012. S. 29. https://www.birmingham.ac.uk/Documents/college-eps/college/stem/additional/Teaching-Mathematics.pdf [27.06.2019]

[3] Research has shown a negative correlation between math anxiety and math performance. For a discussion of this phenomenon, see, for example, Bjälkebring, Pär. „Math Anxiety at the University: What Forms of Teaching and Learning Statistics in Higher Education Can Help Students With Math Anxiety?" *Frontiers in Education* 4 (2019). doaj.org/article/0e38dc21f2224f3ebc57ef856ed3273d.

[4] See, for example, Ableitinger, Christoph, and Angela Herrmann. *Lernen aus Musterlösungen zur Analysis und Linearen Algebra: Ein Arbeits- und Übungsbuch*. Wiesbaden: Vieweg+Teubner/Springer 2013; Atkinson, Robert K, Sharon J Derry, Alexander Renkl, and Donald Wortham. „Learning from Examples: Instructional Principles from the Worked Examples Research". *Review of Educational Research* 70, Nr. 2 (2000): 181–214.

[5] For an example see Frettlöh, Dirk, and Mathias Hattermann. „Konzeption eines Mathematik-Förderprogramms für Informatikstudierende der Universität Bielefeld". In *Lehren und Lernen von Mathematik in der Studieneingangsphase*, edited byAxel Hoppenbrock, 197–212. Wiesbaden: Springer, 2016.

[6] Atkinson, Derry, Renkl, and Wortham. „Learning from Examples." [4]

[7] Nilson, Linda B. „Learning in Groups". In *Teaching at Its Best: A Research-Based Resource for College Instructors*, 3rd ed., 155–66. San Francisco: Jossey-Bass, 2010; Nilson, Linda B. „Quantitative Reasoning and Problem Solving". In *Teaching at Its Best: A Research-Based Resource for College Instructor*s, 3rd ed., 197-98.

[8] For examples see, for instance, Kämper, Andreas, Kathrin Wolf and Monica Serbu.„‚Problembasiertes Lernen' (PBL) in Mathematik und Technik – Ein Ansatz für mehr Anwendungsbezug und Praxisnähe" , presentation at HD MINT Symposium 2013. https://www.hd-mint.de/wp-content/uploads/2013/10/HD-MINT-Symposium_PBL_in_Mathematik_und_Technik.pd [08.02.2021]; see Grieser, Daniel. „Mathematisches Problemlösen und Beweisen: Ein neues Konzept in der Studieneingangsphase". In Lehren und Lernen von Mathematik in der Studieneingangsphase, edited by Axel Hoppenbrock, 661–75. Wiesbaden: Springer, 2016.

[9] See the material for "Vorkurs Mathematik" at the University of Vienna: https://mathematikmachtfreunde.univie.ac.at/vorkurs/themenbereiche/ [08.02.2021]

[10] Novak, Gregor, A. Gavrin, W. Christian, and E. Patterson. *Just-In-Time Teaching: Blending Active Learning with Web Technology*. Upper Saddle River, NJ: Benjamin Cummings, 1999; Simkins, Scott, and Mark H. Maier. *Just-In-Time Teaching: Across the Disciplines, Across the Academy*. Sterling, Va.: Stylus, 2010.

[11] Nilson, Linda B. „Inquiry-Guided Learning". In *Teaching at Its Best: A Research-Based Resource for College Instructors*, 3rd ed., 175–79. San Francisco: Jossey-Bass, 2010.

[12] Siehe z.B. Brame, Cynthia. „Just-in-Time Teaching (JiTT)". https://cft.vanderbilt.edu/guides-sub-pages/just-in-time-teaching-jitt/ [08.02.2021].

[13] Roth, Jürgen. „Lernpfade - Definition, Gestaltungskritierien und Unterrichtseinsatz". In Medienvielfalt im Mathematikunterricht, Lernpfade als Weg zum Ziel, edited by Jürgen Roth, Evelyn Süss-Stepancik and Heike Wiesner, 3 -25. Wiesbaden, Springer Spektrum, 2015.

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