Using quizzes to discuss and link different perspectives on physics

Sebastian Diehl, Dennis Hardt, Thomas Müller, Tom Zander, Romain Daviet: THP
Mariyam Fatima, Stefan Brackertz: PH1

Quizzes known from inverted classroom concepts have been used in several courses in Cologne as easy to implement tools to development existing and quite classic teaching formats (Q&A session, exercise class) from „shut up and calculate“ towards a focus on scientific discussions.

Quizzes, short multiple-choice questions students have to vote on in class, have the advantage that they implement activity and feedback by every student of a plenum in short time. These so called clickers (referring to the hardware of audience response systems often used, see 1) have become prominent in the last years in the context of inverted classroom as a tool to stimulate cognitive activity during contact time. Among other tools their effectiveness has been empirically proofed, see i.e. 2 for a survey. Nevertheless, these empiric results focus very much on exam results in settings where the expected learning outcome is clearly defined and on a very much reproductive level. Although present in literature (1) aims like fostering communication, giving insights into thoughts and difficulties of students, not to mention into their interests are barely addressed by the empirics. In addition most research has been conducted under regulations like non-free course choice, compulsory attendance, marked homework and so on.

In the Cologne Physics Department quizzes have become common during Corona restrictions and had no decline in popularity afterwards. In this context well-evaluated dimensions of clicker use like exam results were not so much in focus but the question how to keep up as much participation, fun and communication as possible without introducing carrot and stick measures. In fact, (not only) in these times the main difficulty was that students had monetary or mental health issues, self-doubts, struggling motivation and quit courses or university in general before they could even participate in an exam. Moreover, the main challenge of the contents in question was not its quantity, which makes it difficult to remember, but the fact, that students had to gain problem-solving experience and had to develop vivid and interconnected pictures of rather abstract concepts. This is typically done by hours of peer-discussion about just a single page of a textbook triggered by the need to understand the problem definition of out-of-class-problem sets.

Triggered by this experience, every now and then courses are implemented as inverted classroom now[1] and quizzes are also used in this context, see i.e. 3, but the main usage of quizzes is within exercises and question-and-answer-sessions of more classical course formats.[2] Quizzes are used as a concise repetition tailored to the program of a certain exercise lesson to provide a re-entry point; this has already been discussed in another article, see 9. This article focuses instead on the use of

1 Some inverted-classroom courses are available as open education resources, see 4,5,6.

2 Quizzes have also been tried to break up conventional lectures, but this turned out to be quite difficult if students have already settled in a passive position in a „stadium-style seating“ (7). Instead, short brakes for coffee, smoking, peer-discussion involving also the teacher seem to work much better here.

quizzes to link topics and points of view and to zoom in from an overview landscape of a physical field to details of a calculation and back. This will be exemplified by two different course formats.

Connecting and zooming in networks

As known by theory of cognition „we form concepts (…) by building the web of relations that constitutes the conceptual content. (…) we now take up the web of relationships to be built at a corner and unfold it step by step. (…) Wherever, in the course of explanation, we notice that an element or relation we thought we could presuppose is not present, we resolve the element or relation in turn into the web of relations that constitute it.“ The aim is „to give flexibility and (…) to enable the student to make (…) the necessary transformations, variations etc.. (…) Only in this way [operators and concepts] become instruments of a vivid thinking. (…) A concept acquires (…) transparency in the course of working through it. (…) Working through means that the thinking moves on different ways through a net. (…) In the course of such a working through, we also cleanse the concept of the dross that clings to it from the first elaboration. The essential connections emerge in clarity. The concept becomes a mental map (…) in which the student can move freely and independently.“ (8)

In traditional university physics teaching formats this is in party taken into account by the design of the out-of-class tasks; each task „take[s] up the web of relationships to be built at a corner and unfold[s] it“. Although this is typically not done having this idea explicitly in mind, most experienced PhD students or postdocs designing these tasks follow this principle by enculturation. Especially for advanced students giving exercise classes, it is a bit more difficult, but still common to „resolve the element or relation (…) into the web of relations that constitute it“. The reverse process, in contrast, zooming out and linking different corners of the web of relations, is not explicitly addressed by most traditional university physics teaching formats. – But nevertheless, it‘s at the heart of the competencies required in oral exams and with some limitations by short questions „quickies“ typically used as opener of written exams.

Thus, addressing this process being not explicitly part of the teaching format requires a lot of experience of the course team and also the freedom and courage to take time for this:

„To notice that a partial term or a partial relation does not yet exist, however, requires some didactic skill by the teacher. In the course of an explanation, he must notice from subtle signs of discomfort in the students that something is not right. (…) Another problem arises from the fact that the sequence of substeps of an explanation or a development carried out together with the students has the form of a chain, i.e. a linear process, while the result is a network. The explainer has to weave the web of relations like a spider from a single thread. In doing so, it is not possible for the student to keep the whole web woven so far present in his mind at every moment. (…) The explanation must therefore return again and again to the points where it has left an element, take it up again and continue spinning from here.“

The experience of the authors is, quizzes help to address this issue in an intuitive manner: Questions which make students or tutors getting lost in the details of long calculations do typically not occur because of the requirement that the questions must allow students to more or less answer spontaneously. Out of the questions fulfilling this requirement the discussion is naturally dominated by those which address a link in the „web of relations“ that is unclear to the students. This is because the discussion of questions, which only address reproduction of knowledge, as well as the discussion of questions, which are clear to the audience, just ends after a few words.

Nevertheless, this requires that „the teacher has present in mind the network of relationships to be established“.

Teaching formats

Although the formalities of most courses in the Cologne Physics Department are quite similar consisting of lectures, out-of-class exercise tasks to be done and handed in by students in groups and exercise classes addressing these tasks in some way, the functions of the respective parts of these courses differ a lot.

A prototype theory lecture, for example, typically tries to sketch a landscape of a field and on the same time introduces exact definitions and math methods to operate these. Accordingly, the exercises typically focus on zooming into the application of this knowledge with the aim of working out a vivid and sometimes comic-like idea of the abstract knowledge on the one hand side and experience, productive strategies and versatility of the introduced maths on the other hand side.

In contrast, most experimental lectures are much more phenomenon-driven, thus already giving comic-like ideas and intuition, but the bigger picture is more aphoristic, raising open questions and lots of open links to other fields in physics and beyond, engineering applications and history of physics. Thus, the challenge of application during the exercises is not so much complicated maths handling abstract objects and lengthy calculations but rather finding an appropriate fruitful starting point to zoom in understanding the limitations of models. It’s not so much about development of a vivid idea of abstract, but well-defined concepts, but rather to link the different islands of knowledge build up in the lecture and understand the link between similar, yet different concepts and approaches. In retrospect, this is why the emphasis of the different aspects mentioned in the last section turned out to be different for the theoretical and the experimental courses:

In the theory courses quizzes have mainly been used to

1. resume, if the red string the “web of relations” has been woven of in the lecture seemed to be snatched for students,
2. add a zooming-out and a bottom-up perspective to the standard zooming-in top-down perspective of the exercises – in the bachelor courses with focus on the link between comic-like explanations and very small calculations, in the master courses with a special focus on appropriate decisions which stuff to omit when zooming out,
3. make the knowledge of the lecture platform-independent and working out the work out the load-bearing ropes by changing the perspective from which the lecture material is viewed[3], i.e. “cleanse the [physical] concept of the dross [and artifacts] that clings to it” from the chosen language of the “the first elaboration” in the lecture and the math tricks used in “the first elaboration” of applications.

In the experimental courses quizzes have mainly been used to

1. clarify how open ends of the red strings making up the “webs of relations” of the different islands of knowledge woven in the lecture belong to each other,

3 This is different from changing the degree of detail; in the language of manifolds it’s like exploring the transition function between different maps of a manifold compared to exploring a certain map in more or less detail.

2. solve off messes of glue students used as associative quick&dirty-helpers when the lecture huddled over details of a relation to keep the bigger picture in view and fix the resulting holes in web of relations by going back to first principles.
3. rush into non-appropriate details of comic-like ideas, discuss where they come from (for example historic misunderstandings, wrong generalizations of approximations) and clarify the misunderstandings behind.

Discussion sessions in theory courses

As students typically clarify a lot of questions and discuss a lot about physics during unplanned and informal encounters in university, Mensa or pubs during the Corona closings several lecturers introduced additional question-and-answer hours as a compensation offering. Breaking the silence, encouraging students to really ask questions, not to mention to really engage in discussions turned out to be rather difficult. This changed a lot when the authors started to use quizzes as a starting point of discussions which then, in turn also led to lots of questions by the students.

In contrast to quizzes interspersed in a lecture a separate meeting turned out to be advantageous:

- There is no felt pressure to go on with the lecture.
- There is an active start in the very beginning, so students have not already settled in a consumption mindset that has to be laboriously broken up.
- The topic to discuss is not just seen for the first time.

The questions students come up with in such an environment are quite different from those in discussions directly linked with a lecture[4]: They were not about details like a missing sign, but more like: „Whats the point of...? What‘s the logic? Why are we doing it?“ Of course, such questions can always been asked, but it turned out that a certain time of maturity and reflection is necessary for students to separate important stuff from banalities and come up with such questions. And it’s also important that there is a setting of mutual discussion, not only of clarifying requests. This was also fostered by the fact that most of the discussion hours have been hold together by the professor and tutors and they often explained the same point from a different point of view or run into (sometimes controversial) discussions about there own understanding about „what‘s the point“.

In the more basic Bachelor courses the bridge between the high level and challenging content of the lecture and the not so trivial out-of-class exercises was established by practical quiz questions in between which put an important phenomenon of the lecture in the simple-most technical context. Although there have been some similar questions in the Master courses, too, especially when new mathematical ideas have been introduced, the questions in the master courses dealt more with qualitative understanding. For example it was asked which approximation is appropriate in a given context or some graphs have been presented and students were asked to decide which is from a renormalization.

In the discussion hours after a multiple choice question has been presented the students got about 3 minutes to think about it and were also sometimes asked to discuss with their neighbors. They anonymously voted, the voting result was presented and if people volunteered, they presented the reason for their vote. This transitioned seamlessly into quite extensive discussions in which students

4 It‘s also not so natural that students come up with this type of questions in exercise classes as there is often a more pragmatic mindset dominant which is focused on the solution of a certain task.

came up with a lot of additional questions. Per meeting typically three questions have been discussed like this and the meetings which have always been announced with an open ending took between one and sometimes several hours. The experience is that the duration of the discussion depends on the chosen room more than expected. The format works with online meetings, but a real meeting is much better; compared to a lecture hall seminar rooms foster much more interaction among students and not only between students and lecturers.

Although the participation in the discussion hours fluctuated very much, it was always good and the discussions brought people to life. The feedback of the students was despite some critics on a few quiz questions, which seemed to require more than one line of calculation for the vote, very positive. Although additional and voluntary work for students as well as for the lecturers, people liked the meetings as the format seems to always converge to the questions, which are really relevant for the participants and about which they rack their brains either way. And it is very encouraging and instigates also out-of-class discussions if students see, that others have the same misunderstandings or rack their brains about the same questions. So even when the discussions took a long time, it was very rare that students left earlier. The irregular participation of most students seems to be linked to their current list of non-postponable duties.[5] The experience of the authors, especially from oral exams, is that most students think either assembler-like or have high-level-knowledge and that it is rather difficult to supplement and link the other later on. Lots of students recognize this even if they cannot formulate the problem and find this a very unsatisfactory aspect of their student life. The discussion hours seem to help a lot to develop both, low-level operational competencies and high-level knowledge, in an integrated manner.

Although in principle less cogent quiz questions do not do a lot of harm as their discussion is just over in no time, at least some questions need to be on point to make the format working. This is why the authors of this article who used this format in several courses on Quantum Mechanics (mandatory course of the bachelor program) and Quantum Field Theory (specialization of the master program) put a lot of effort in the development of the questions, at the beginning as a team, after some experience in a row. As a result, all questions used turned out to provoke quite fruitful and lively discussions and we think the format also works as the students perceived that the course team was kind of enthusiastic. Nevertheless, to regularly establish this format there is the need for a systematic answer how to deal with the extra work that must be done to design the quiz questions and to hold the discussion hours which has been mostly done by two people together. This is not only a question of money as the PhD-students and postdocs involved also need time for their research work. The people doing this additional work on the one hand side must be involved in general in the course and also need to be quite advanced in the subject. On the other hand, as the idea of the discussion hours is to have a look at what has already been learned a week or more ago from a different perspective, the questions don‘t need to exactly fit what is going on in the lecture or the exercise classes in the respective week. Over the semesters different approaches have been tried. The best so far is to have one person more than one would have without the discussion hours and to swap who holds exercise classes and who does the discussion lesson.[6] According to our experience, it does no

5 The regulations regarding out-of-class tasks were different for the courses described here. Despite the fact that students skip courses during the semester – especially in the master program students typically try out a lot of courses in the beginning of the semester – the participation in the discussion hours did not seem to depend on whether students had handed in out-of-class exercises or not.

6 In the courses discussed here there are several exercise classes offered in parallel to have a group size of the exercise classes of around 20 students. Depending on the available resources it‘s maybe better to have an exercise group less and bigger groups to allow for a discussion hour as most exercise groups shrink nevertheless over the semester.

harm if the tutor of an exercise class changes once per semester as long as tutors stay in contact. This is realized by a short meeting of all tutors every week to discuss what‘s going on in the lecture and the exercise classes and to do a common brainstorming what could be addressed in the quizzes.

Exercises of experimental physics master courses

In an international master program the background of students is obviously most diverse regarding labcourses which in many countries don’t exist in the bachelor programs at all. But in fact, the background in 20th century experimental physics in general is very diverse, also among students from different German universities. In this setting, a lot of students only recognize if others know certain topics very well they have never heard about themselves but they don‘t recognize that the reverse is also true. This is a serious problem and it is not only frustrating but intimidates lots of students to work with others.

Molecular physics, the field in which the authors have addressed this using quizzes, is a whole lecture in some bachelor programs, just a sentence in an introductory lecture on quantum mechanics, part of astrophysics or part of a chemistry minor subject in others, to just name a few of the possibilities. The way it is done in the Cologne master program has strong overlap in content with chemistry and overlap in methods with nuclear physics. The latter is because both are taught in an extended Schrödinger theory approach although particle annihilation / photon absorption and particle creation / photon emission in principle would require a quantum field theory. Thus, symmetries, conservation rules and selection rules being independent from the chosen theory framework play a big role. In addition, the Schrödinger theory is on the one hand side phenomenologically extended towards quantum field theory by addons like dipole transition operators and on the other hand side towards Newton theory by a lot of approximations. This approach is side quite intuitive and also schools the physical intuition of students itself, but it has also hundreds of open links and a high potential for wrong associations.

What is also shaping the discussed courses is that handing in out-of-class exercises for correction is part of the course course concept, but (like participation in the meetings) not mandatory in contrast to other challenging courses the students typically participate in in parallel.

A third relevant circumstance is that at least the beginning of the Molecular Physics I course has to be held hybrid as some students cannot make it to Cologne in time for the start of their first master semester due to visa difficulties.

The courses described here consist of a lecture and an exercise class[7]; the exercise class is hold by PhD students and/or postdocs, often as in the case described here in team teaching including a colleague with chemistry background. For each exercise class the students get a collection of out-of-class tasks and are asked to hand in solutions in small groups the day before class. The tasks are corrected „overnight“, but are not marked. Instead of points the students get an individual learning recommendation if appropriate. The corrections are sent to the students via mail a few hours before the exercise class starts together with a suggestion what part of their work and/or their mistake they could present in class and why the tutors think this is useful for the whole class. The experience is that prepared like this the students are much more willing to give a short presentation (maximum 3 minutes) during class and that these presentations are much more on point giving the class a completely different dynamic. In fact, thinking about the learning recommendations and the presentation suggestions is also a very valuable preparation for the tutors to hold a good class.

To address the different backgrounds and interests of the students, there are many more exercises on each exercise sheet than the students are expected to hand in. There are for example five tasks with the recommendation to chose two of them. Every task is carefully motivated including some hints

7 There are 10-20 students attending the course, so there is just one exercise group.

regarding role of the task within the course, relevance of the task regarding physics as a whole, historic development of physics and sometimes discussions in society, useful preknowledge from other courses and addressed methodical skills. The idea is that making a decent choice in the best case in a group discussion is very important for the maturing process of young scientists. In fact, we don‘t know the impact; the student feedback is that they like the motivations but merely decide by pragmatic aspects and their mood. For instance, tasks requiring literature work are only done when students feel relaxed; tasks, which can be started by blindly pushing formulae, are done in hectic times leaving out the discussion which is the main part of the task.

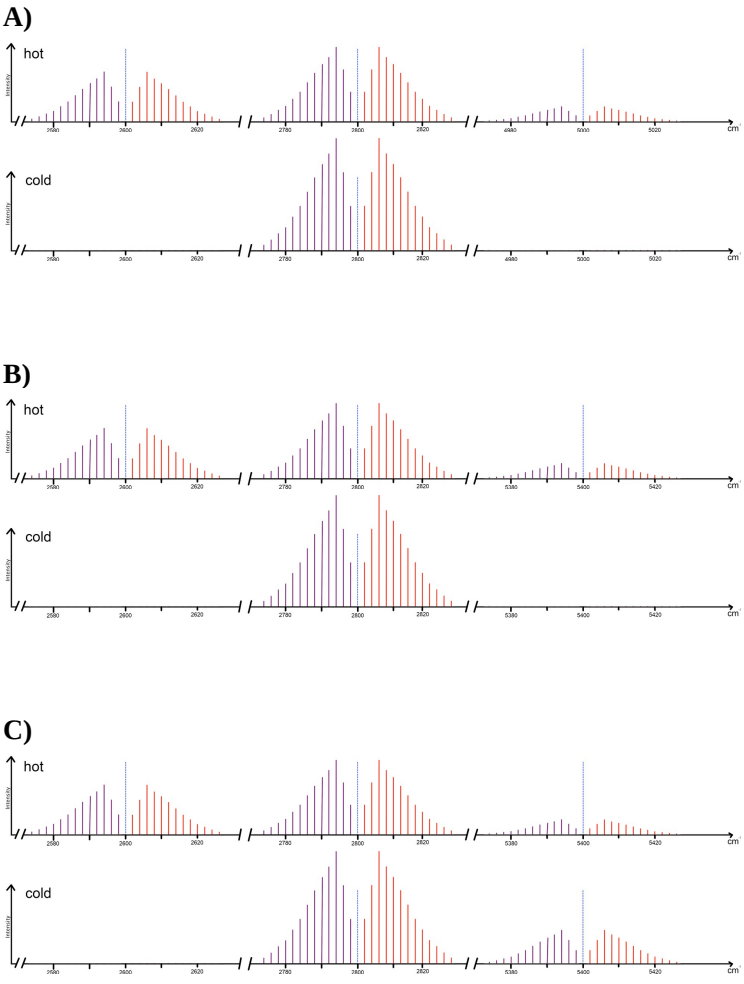

Abbildung 1: Quiz question from Molecular Physics I exercise class

The tasks are designed in such a way that they are meaningful as they are but at the same time just one of at least two aspects of a bigger problem. Later on in class, not the tasks are discussed but the whole problems including the task. Thus it is ensured that the class is interesting, regardless if students have done a certain task or not, and that doing the tasks is nevertheless motivating and fruitful for the whole class. If possible, there is a mixture of different types of tasks on each exercise sheet, for example application and discussion of a model known from lecture for a certain molecule, establishing links between different chapters of a lecture, literature work etc. Special emphasis is placed on always having tasks that value and explicitly incorporate the students' prior knowledge and/or ask them to work together. For example: „Find three students, one being experienced in nuclear physics, one being experienced in solid state physics and one being experienced in quantum field theory. Ask them to write down their respective definition of ‚quasi-particle‘. Taking these definitions into account: What is the common core idea of the concept?“

As already mentioned, the exercise classes are dedicated to problems or topics, which include one or two out-of-class tasks the students have handed in a day earlier as aspects. Quizzes are used to open a block of the exercise class dedicated to such a topic.[8] They typically address the topic from a different perspective as the out-of-class task and can be approached on different levels.[9] Dependent on the questions, the students are either asked to discuss the question with their neighbor for about 5

8 Depending on the needs of the students there are also short breaks between the blocks and a quiz question after such a break helps for finding focus and actively involve everyone after the break.

minutes before voting or they are asked to more or less vote immediately and discuss with people who have voted differently[10] afterwards. In both cases, students are typically willing to share thoughts with the plenum afterwards as a starting point for the main discussion. In the course of this discussion later on also (parts) of the out-of-class tasks are presented and sometimes further quiz questions included. The quizzes turned out to be extremely useful not only to activate students[11] and to get an idea of the students‘ understanding of the topic. They rather naturally and unerringly point out was has to be discussed.

Although the team collects ideas for quizzes in a shared document, the questions used are always chosen and finalized after having seen what the students have handed in: When correcting handed in exercises one often find parts of solutions where it is obvious that students don‘t know exactly what they are doing or where it‘s obvious from details that they have a non-appropriate comic-like idea in mind (see discussion above), but are experienced and oriented enough to write it down in a way that it is not wrong. The quizzes are always designed to exactly rattle into that point which often triggered time-consuming discussions even about the physics the students learned to calculate in their first semester but never understood. In the evaluation the students agreed that these discussions, which cleaned up the mess from „shut up and calculate“ of their earlier physics carrier, were the most important motivation to take part in the exercise classes and to hand in out-of-class tasks, not Molecular Physics.

In general it turned out over the semesters that in a setting in which doing the out-of-class work as well as the participation in the exercise classes is voluntary and in which students have a high workload, it is crucial that students consciously experience that their participation changes the way the course goes on. This is why it was always made explicit that and how the design of the exercise classes as well as the out-of-class tasks results from the student input, for instance: „Handing in out-of-class tasks is not only helpful for you to get feedback on what you have done, it‘s necessary for us to do an exercise which is useful for you.“ „Many of you wrote a sentence like XY. It‘s not wrong, but it‘s also not exactly correct. This is why we have the following quiz question for you.“ „Because some of you asked about XY in the last exercise class, we put the following task on this exercise sheet.“ Maybe, the „overnight“ feature is probably difficult to realize for bigger courses with several exercise groups, but it is perfect to ensure that students not only know in principle, but really experience that their participation matters. A typical schedule is as following:

- Thursday noon: Deadline for the students to hand in their result.

9 For example properties of selection rules can be discussed using symmetry – an approach which is also doable for students who have never learned anything about Molecular Physics – but they can be discussed based on the definition of the transition dipole moment as well. So the quiz questions have been designed in a way that both approaches can be used to exclude or include a part of the answer possibilities, but both approaches must be combined to decide for all given answers possibilities if they are correct or not.

10 Voting is not done anonymously, but just by raising hands.

11 The idea to use quizzes originally came up in a discussion about how to activate and integrate the online participants who are compared to the other participants typically very silent. Although this rudimentary worked, we found an interesting phenomenon: When online participation was offered typically two to three students participated online and only half of them was participating from another part of the world. The rest was sitting in the next room and afterwards joining for lunch. Being asked for the reason at least a third of the course said they always decide shortly before the start of an exercise class if they want to actively participate or just „watch the exercise class“ depending on their current energy level. When they decided for active participation they joined in presence, otherwise they joined online as facilitates hiding. On the one hand side it‘s astonishing that they joined at all when they think they don‘t have enough energy to actively participate as everything is recorded. On the other hand side it‘s astonishing that the quizzes allowed to also activate the hiding people – at least to some degree.
In this discussion one has to keep in mind that most students in our program work in parallel and non-EU students run into visa difficulties when they reduce the number of courses they do in parallel too much.

- Thursday afternoon: Correction
- Friday 8am: Deadline for the tutors to send back the correction
- Friday morning: Common coffee of the tutors to discuss the choreography of the exercise class and finalize the quizzes.
- Friday noon: Exercise class
- Friday afternoon: Finalization of the new exercise sheet
- Friday evening: Publication of the new exercise sheet

To make this work, the tutors collect ideas of exercise tasks as well as of quiz questions in a shared document whenever they come up. Often, the tutors attended the lectures as an inspiration.[12] A collection of the tasks and questions of the last semesters is also used.

Although some students never handed in anything and some students who always handed in exercises but never showed up but used the recordings, because they had to work, it is very pleasing that the participation and what has been handed in was not worse than in courses with a lot of strict rules, duties and so on.

In earlier semesters without quizzes the following questions have been addressed more explicitly:

- How to design a discussion which is useful for people having done the out-of-class tasks and those who have not?
- How to value and use different background knowledge of the students?
- How to explicitly clarify stuff which is not wrong but problematic in the students‘ comic-like ideas?

What is the physical reason of selection rules?

a) Energy conservation
b) Symmetry
c) Experimental Setup
d) Einstein Coefficients

What does the Pauli principle state?

a) The wave function changes sign if two charged particles exchange.
b) The overall wave function changes sign if two indistinguishable particles exchange.
c) The probability distribution changes sign for a particle exchange if it is equivalent to a rotation.
d) Every factor of the wavefunction has to be either fully symmetric or fully antisymmetric.
e) Two indistinguishable particles cannot exist in the same state.

Features of potentials

Assign:

a) quadratic potential
b) London potential
c) Coulomb potential
d) Morse potential
e) box potential

1) long-distance interaction of ions
2) long-distance interaction of neutral atoms and molecules
3) infinite number of states
4) finite number of states
5) good approximation for low energies
6) sufficient for big distances
7) equidistant energies
8) neglects thermal expansion

What are prerequisites of the Born-Oppenheimer approximation?

a) low pressure
b) localized nuclei
c) low energies
d) electrons are faster than the nuclei
e) the PES looks close to its minima similar to a Morse potential

Abbildung 2: Chosen quiz questions from Molecular Physics exercise classes

Compared to earlier semesters now less students fade out over the semester and the exercise classes were quite lively, the level of discussion much higher and more students participated in additional offerings like labtours.

12 Fun fact: Sometimes students complained about the tutors being too loud tapping enthusiastically on their laptops when they had a good idea.

Overall experience

Quizzes are a versatile tool which can be used in different university teaching contexts. It is not only activating but helps to initiate clarifying discussions on point, even if students are mainly used to „shut up and calculate“. This is especially relevant for learning physics as one of the most important factors of success is that students learn to do group work, which is beyond dividing the work between several shoulders. Although this fact is well known by most people, even master students are often not used to it. In Cologne, the physics teaching environment is designed to push students to group work[13]; nevertheless several students don‘t know how start and make discussions work and then fall back to working alone. But the problem is not only that people don‘t know how to start, but also that people are skeptic: Many bachelor students have experienced group work at school as „someone wants me to do her/his work“; master students from more competitive and judging bachelor programs are used to presenting final results and hiding the steps in between. For them discussing problems and questions in exercise classes seem to feel embarrassing and exposing. A quiz which immediately shows that a lot of people have the same problem and provokes a debate on a contradiction in class, not about the problem of XY.

In view of this it‘s a nearby idea to use some technical help for anonymous voting as done in the discussion hours on theoretical physics. Nevertheless, for the experimental exercise classes the quizzes are done just by rising arms, because this allows to alter on pair students depending on their vote and – more often – more explicit reference among the students in the discussion. This was done making explicit that possible examiners of the students were not part of the exercise classes and in agreement with the students. In fact, after a short time, one could feel the restraints falling. In retrospect this also worked because among the answer possibilities of all questions there were quite obvious ones as well as possibilities all students answered wrong. So everyone had an obvious success and still a lot to learn.

In any case, the experience of the authors is, that you can‘t do a lot wrong when using quizzes as the format itself leads students as well as lecturers, if experienced and didactically trained or not, to the relevant discussions.

Literatur

1. Caldwell, J. E. (2007). Clickers in the large classroom: current research and best-practice tips. CBE-Life Sciences Education, 6, 9–20. https://doi.org/10.1187/cbe.06-12-0205
2. DeLozier, S.J., Rhodes, M.G. Flipped Classrooms: a Review of Key Ideas and Recommendations for Practice. *Educ Psychol Rev* **29**, 141–151 (2017). https://doi.org/10.1007/s10648-015-9356-9
3. https://story.uni-koeln.de/category/lehre/#astrochemie

13 In all courses students are asked and sometimes also forced to hand in labreports, out-of-class exercises and so on in groups. Although directly at the main campus, the physics department has its own building with an open market-like architecture where people meet unplanned, computer pool and library with helpful, trained stuff and big areas inside as well as outside for silent work as well as for discussions, cooking, table tennis and so on. The dates of the courses are chosen in a way that most students, also if they study part-time, have reasonable breaks over the day, not only for relaxing and lunch, but also for out-of-class work. Part of the student driven tutorial program are advanced students wandering between the tables where students work; they do not only offer their help but also initiate student working groups like: „The people at the table over there work at the same task like you. Maybe you want to join them?“ Several professors slightly reform the teaching formats with the aim that students explicitly learn how group work can be fruitful, for instance see 9.

4. https://www.thp.uni-koeln.de/trebst/Lectures/2020-CompPhys.shtml
5. https://www.thp.uni-koeln.de/trebst/Lectures/2020-StatPhys.shtml
6. https://www.thp.uni-koeln.de/trebst/Lectures/2021-CompManyBody.shtml
7. O'Shea, P.M. (2020). Flipped Learning at the University Level. In: Walker, Z., Tan, D., Koh, N.K. (eds) Flipped Classrooms with Diverse Learners. Springer Texts in Education. Springer, Singapore. https://doi.org/10.1007/978-981-15-4171-1_10
8. Aebli, H.: Grundformen des Lernens; Klett, 1977, 10. Auflage, S. 201 ff., quotations are translated by the authors
9. https://studienreform-forum.de/de/forum-2023/beitrage-2023/2023/03/04/gemeinsam-answerk/