Mathematics for the Real World

A conversation with Dr Michael Winckler on a challenged based teaching project

HINT: Hello, dear Michael Winckler, thank you for taking the time today to talk to me about your project on transfer-oriented teaching. This took place in the context of a course to which students from Heidelberg and also international students from the European University Alliance 4EU+ were invited. You and I have known each other for a few years now through collaborations on innovative teaching. In 2007, you obtained the Baden-Württemberg Certificate for Teaching and Learning. If I remember correctly, your first course in higher education didactics in the certification process was on the topic of project-oriented teaching. Can that be?

Winckler: Yes, that is right. I found the topic of project-oriented or transfer-oriented teaching or rather learning interesting because in mathematics we often talk about what this teaching could possibly look like in concrete terms. Mathematics often comes across as very theoretical, especially at university, but many things in everyday life need mathematics to use them. Moreover, it is in the application to real problems or in projects that learners notice whether they have actually understood a theoretical construct, e. g. of mathematics, because they can apply it to projects or general problems. Of course, they also notice what they have not yet understood.

HINT: You are jumping right into the topic of the shift from teaching to learning, i. e. learner-centred teaching. Heidelberg University forms the European University Alliance 4EU+ with the universities of Warsaw, Prague, Sorbonne, Milan and Copenhagen and the learner-centred teaching approach is at the core of that, right?

Winckler: Exactly! One of the goals of this European university alliance is to promote and foster innovative teaching across European universities. 4EU+ has committed itself to the principles of learner-centred teaching. In this context, research-oriented and transfer-oriented teaching formats are the two concepts whose effectiveness as a learning-promoting structure has been well studied and which are to be pursued, implemented and adapted to the respective needs within the framework of the alliance. However, there are many definitions and formats for project-oriented teaching in particular. Project-oriented teaching with

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real projects, or mock-ups, service learning, transfer-oriented teaching or challenged-based teaching are just a few ideas and concepts of what application-oriented teaching can look like.

HINT: And at the Interdisciplinary Centre for Scientific Computing (IWR), together with the graduate school HGS MathComp, you have developed and tried out a special format of challenge-based teaching, the Integrated Think Tank, from 4 – 8 July 2022. On your homepage, you describe this as "one week of intense modelling real world problems with two renowned industry partners". Can you briefly describe what this means?

Winckler: Yes, with pleasure. In a nutshell, you could say that an Integrated Think Tank is a one-week challenge workshop with industrial partners, in our case it was two partners, namely SAP[1] and Volume Graphics[2]. Students and lecturers work together with experts from the companies to investigate topics from the area of research and development relating to current developments at these companies. It is also a new approach to generating research ideas at the industrial-academic interface.

HINT: Topics from the field of research and development – how can I imagine that?

Winckler: The goal of the ITT is not – as in other examples of project-oriented teaching – to have generated creative solutions to certain problems at the end of the workshop phase. On the contrary, I would even go as far as to say that the challenges or questions would have been too narrow or too simple, if students could have generated actual solutions within the one workshop week. Aim is not to "solve" problems, but to understand big challenges, identify and test preliminary routes to a solution and map mechanisms to carry forward. To put it bluntly, one can say that the aim of the ITT is to formulate actual research topics as *thesis projects outlines* (master or PhD) that can be worked on in the field of mathematics. Imagine that the company representatives come with rather a vague cloud of topics or questions that

[1] Founded in 1972, SAP has changed the way companies work. With its system oriented program development SAP offers a software that integrates all operational processes and allows it to process data in real time. Today, SAP is also working in cloud solutions for their customers.
[2] Since 2020, Volume Graphics has been part of Hexagon. Hexagon is a global leader in sensor, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications. Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

are fleshed out in the course of the week. At best, specific questions can be identified at the end of the workshop week and the university and the partner companies join forces to convert the project outlines into actual research projects.

HINT: That sounds very exciting. And who is the format aimed at, who could participate?

Winckler: The target group was primarily Master's students and doctoral candidates from Heidelberg and the 4EU+ partner universities. We were open to participants from very different fields of study, although the core naturally came from mathematics and computer science. The ITT is most successful if different students from various fields work together aiming to mathematically model approaches to applied challenges from diverse perspectives. In addition, we had invited the University of Bath for this ITT, but Corona prevented us from recruiting participants from there.

HINT: So how many participants did you have?

Winckler: In concrete numbers, 35 master's and 20 PhD students participated in the ITT. We had applications not only from maths, but also from chemistry and physics. For the application, the students had to submit their transcript of record and convincingly explain their respective interest and expertise in a letter of intent. For the group formation during the ITT week, these heterogeneous prerequisites of the participants were taken into account and actively used to put together teams that were as diverse as possible. In the selection process, we were less concerned with selecting applicants according to grades, but we wanted to reserve the possibility of rejecting those who were primarily interested in company contacts and who did not really want to contribute to the ITT project.

HINT: With a total of 55 participants, that's quite a lot for a participatory teaching format. How many teachers were involved during the week? Actually, is "teacher" even the right word? Would you rather say principal investigators, because it's about defining research questions and possible projects?

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Winckler: During the ITT week, seven teachers were actively involved the whole time, which is actually a bit few. Moreover, I would say they work in their role as academics or scientists who mentor the student teams. You need at least one mentor per group. And be aware that you really have to take the time to explain to your colleagues how an ITT works and what the goal is. Especially if the academics join the endeavour with a more classical understanding of teaching, it is important to explain the role as a facilitator of the learning process. It is imperative to describe how you can support

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the learning of the participants through questions. One needs to emphasise that the ITT is a teaching-learning module, this is important. My piece of advice to colleagues is to make their own implicit process of knowledge generation explicit to students in the face of such challenges. So that the participants are invited to participate in my own approach – but then to be open when they chose their own alternative route.

HINT: And what does the learning of the participants look like during the ITT? How do the students get to work? How does that develop concretely over the week?

Winckler: With all the openness, creativity and improvisation that must be present in the ITT and that is required of all participants, there needs to be clear moderation throughout the week, i. e. process guidance that steers and structures the individual phases so as not to get lost and to have results at the end.

As already described, the workshop lasted a total of five days (see Fig. 1). On days 1 and 2, real-life challenges from the R and D sector were presented by the industry partners in the mornings and substantiated in the plenary session through follow-up questions. In the afternoon, the work continued in working groups. These teams were – as described above – put together by the process facilitators in order to bring together heterogeneous expertise and diverse interests. In this group phase of the ITT process, ideas were collected on all challenges that had been presented by the collaboration partners in the morning. These intermediate results were noted on cards and clustered into main ideas at the end of the day. At the learning objective level, individual ideas and concepts had to be set in relation to each other already in this work phase. The teams were mixed up again by the process facilitators between day one and two, so that the participants could also practise forming arguments and representing opinions to different group members. In the evening of the second day, the process facilitators sorted and mapped the topics together with the plenary as an interim summary, which resulted in the identification of a total of 15 topics. The list of challenges and topic clusters, as well as the list of the participants in the teams, were also documented and shared with all collaborators, so that everyone was informed transparently about the progress of the process at all times.

“As a mirror of the ‘real world’, the ITT really attaches great importance to diversity (previous knowledge) and coherence (interest) in the group composition of the teams.”

The teams for days 3 and 4 did not come together freely either, but were constituted by the facilitators once again in such a way that people with similar interests but different expertise worked together. As a mirror of the “real world”, the ITT really attaches great importance to diversity (previous knowledge) and coherence (interest) in the group composition of the teams.

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The teams for days 3 and 4 then worked on mathematically modelling the challenges presented by the industry partners and selected in the plenary. The aim of this work phase is to draft a proposal for a project idea, review literature and identify milestones.

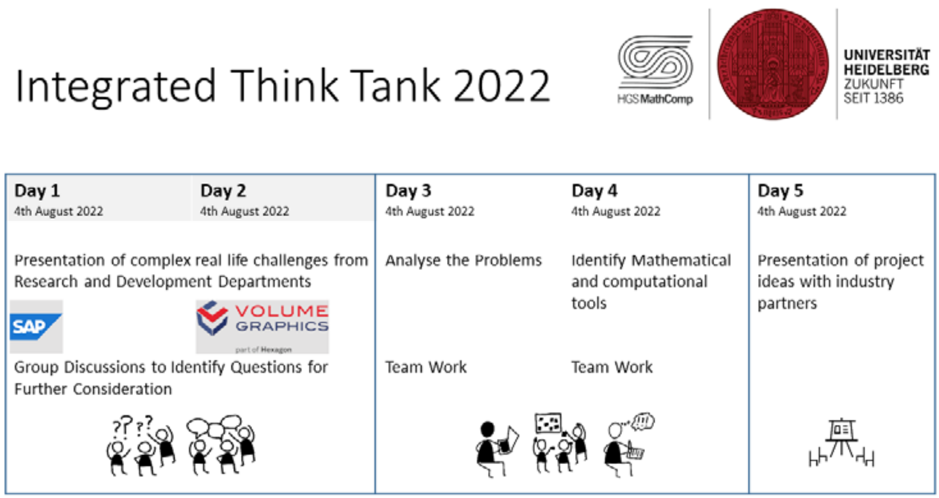

Fig. 1
Structure of the ITT challenged based workshop

HINT: Can I then imagine that what happens in the working groups with the challenges from industry is exactly what you would do as a mathematician in such a company or as a consultant with a company?

“This is exactly how the application of technical knowledge becomes competence, namely when the knowledge is applied to unknown questions or challenges”

Winckler: From a learning perspective, that is precisely what is interesting about such a format: students, but also we scientists, are building confidence in industrial problem formulation. In addition to mathematical modelling of real-life challenges, the participants also learn to present their ideas to industrial partners and to defend them in discussions. This simply goes far beyond the presentations required in a degree course or colloquium. Moreover, this is exactly how the application of technical knowledge becomes competence, namely when the knowledge is applied to unknown questions or challenges – and no solution is in sight at first. In contrast to assignments at university, it is not even certain whether there will be actual solutions to the problems. This also requires curiosity and a high level of intrinsic interest, in order to be able to deal with frustration if necessary.

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HINT: As you need in any research project.

Winckler: That's right – this again makes it clear that transfer in the context of challenged-based teaching and learning does not only mean that projects are carried out with industry partners, but also under real-life conditions where the outcome is unclear.

In order to achieve results despite all openness, continuous communication between clients (companies) and consultants (ITT participants) is essential. Therefore, we repeatedly had hybrid interim presentations with joint discussions with the industry partners during days 3 and 4. The industry partners were not present all the time but connected via video conference systems. Here, the teams presented the first ideas they had developed, but were also able to ask questions again in order to concretise the requirements. At best, this iterative process led to the optimisation of the real-life challenges.

HINT: As you just briefly outlined, communication between industry partners on the one hand and academia on the other plays a very important role. Beyond knowledge of mathematical modelling, the ability to communicate in this way seems to be the essential competence that is needed in your graduates and that the students can also practice in this format.

Winckler: It is not for nothing that we describe our ambition on the IWR homepage as passion to develop computational methods that enable trail-blazing applications. Our work transcends the boundaries of disciplines or faculties, and bridges scientific cultures from engineering to the humanities. That's what our graduates have to be able to do. Although detached from real discussions, opportunities for presentations are important in the course of studies – but no matter how well those presentations are being delivered, as a football fan you end up asking yourself "can they show that on a rainy night in Stoke"? The structure of the ITT offers a completely different opportunity to practise and test precisely this kind of communication, which bridges the gap between science and application.

"ITT as an example of constructive alignment, so to speak."

HINT: to stay with English proverbs: the proof is in the pudding? The ITT is both a learning environment and a formative assessment.

Winckler: Precisely! We describe the HGS MathComp as the place where methods meet applications. Our Graduate School offers national and international students a uniquely structured interdisciplinary education. The program enables our students to pursue innovative PhD projects with a strong application-oriented focus anywhere from mathematics, physics and chemical engineering sciences to cultural heritage. At IWR we bring together mathematical methodology with topical research issues. These are the educational goals, and the ITT offers the appropriate learning environment in which this can be practised and experienced. And in the ITT the communication with the

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companies is the aligned assessment. ITT as an example of constructive alignment, so to speak.

HINT: As a non-mathematician, I would not have thought how relevant communication is in the discipline.

Winckler: We hear that repeatedly. However, think about it that way: Mathematics for us is a language in itself, a language that is employed whenever someone from a field of application tries to quantify some feature or raises the question of improving some aspect – how do you quantify this improvement? – searches for an optimal configuration need that kind quantification. In order to formulate topical research issues using mathematical methodology we and our graduates must first be able to communicate with partners for whom we want to develop mathematical solutions. This integrated process can best be understood by looking at the modelling cycle, in which the interfaces between us and our partners become much clearer (see fig. 2). The framework of the question in view is defined as a specific area in the real world. Experts from application fields describe the knowledge about this lens area in data, charts, films, first principles and heuristic correlations, a collection that we call physical model.

“Mathematics for us is a language in itself”

In an interface and translation step, an abstraction of this physical model is generated, using our language, the language of mathematics. This is when we arrive on home soil: We use our toolbox of models to come up with a description that is quantified and leads to structures that are either well known or have to be investigated to discover new mathematical theory: The model problem is solved. When studying, at the end of this mathematisation students usually meet a result, the solution of an equation, however complex it may be. Thanks to the supercomputer from the Hitchhiker’s Guide to the Galaxy, we all know that 42 is “the ultimate Answer to Life, the Universe, and Everything”. But in Scientific Computing, the process does not end there: 42 might be the answer or just one answer and it is also important to understand how much this answer can vary with the uncertainty of the input data, the physical model and the solution method. So the second interface task is to transform the solution into the language of the application again and to explain to the client what the answer and its error bounds mean in their application, their language and their world. The ultimate test is to use the process to come up with results that can only be later verified. Derivations from the real world process have to be understood, analyzed and described and often lead to a next iteration in the modelling cycle. For the students during the ITT, this was partially the real challenge: to sketch ways to model and to estimate if the chosen approach leads to a sufficiently useful description of the problem. To actually think open-endedly – without focusing on a solution.

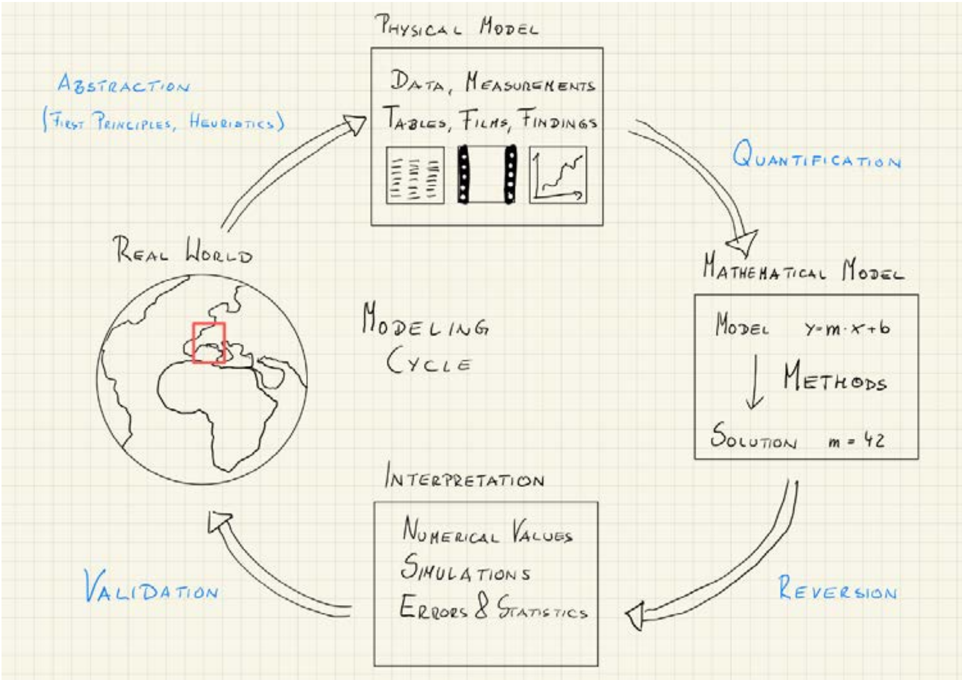

Fig. 2
Modeling Cycle: Language of Mathematics

HINT: That is almost philosophical. I can well imagine that this is not easy for the students because they are expected to do something that is contrary to the culture of the subject they have been familiar with up to now. The imposition character of "intercultural" communication, so to speak. Did the students also describe this in the evaluation?

Winckler: Yes, some do. But for us, precisely this increase in competence, namely the communication of mathematics with the world, is an essential learning goal of the ITT. In this respect, I can understand that some students found it frustrating not to generate even rudimentary solutions during the week – but precisely this back and forth and struggle to find the right ways of modelling is what Scientific Computing for and in the real world is all about.

HINT: OK, from your point of view, this is a very important takeaway for the students. What other benefits are there when students engage in challenge-based learning like the ITT?

Winckler: All participants received a certificate of participation and can have 3 ECTS credited as Key Competence Training for their participation. The main gain in knowledge for the students was certainly working for the first time on real problems to which there is no certain answer in juxtaposition of what they are used to from their studies. This certainly unsettled many, but it also motivated some very much. And it is learning to cope with this insecurity that leads to a gain in knowledge.

Once project ideas have been successfully developed, students can of course apply to carry them out as Master's or PhD projects. And last but not least, the participants of course get direct access to the industry partners for internships or later career entry.

HINT: That's a good keyword. What criteria did you use to approach the industry partners?

Winckler: Of course, we also hope for collaborations from the ITT beyond the one-off event. Our students should get to know companies – ideally those that are located directly on site – that are potentially interesting employers and that also have projects for which they hire working students, for example.

HINT: How did you come up with the idea of this Integrated Think Tank as a specific format of challenged-based teaching?

Winckler: The idea came from colleagues at the Centre for Doctoral Training in Statistical Applied Mathematics (SAMBa) at the University of Bath. Our Heidelberg colleague Prof. Robert Scheichl worked there for a long time and brought the idea over from there. The colleagues in Bath have already conducted 13 ITTs and had great experiences with them. Professor Paul Milewski and Dr Susie Douglas have accompanied our process as facilitators here in Heidelberg. Both have been very actively involved in exporting the format to Heidelberg and we are very grateful to them for this support.

“As a teacher you have to trust the process above all: the students and scientists will develop project ideas together.”

HINT: Are there specific competences that teachers or researchers should have to accompany such a format of challenged-based teaching?

Winckler: Well, the ITT is first and foremost a truly learner-centred format. Above all that teachers or academics should really see ourselves as mentors. In concrete terms, this means in the plenaries at the beginning, for example, setting a good example by introducing yourself with questions that make your own approach to the challenge explicit. But after that you have to gradually with in order to leave room for active learning. The ITT should be understood as a collaborative environment where all substantial contributions of participants should be acknowledged as the projects develop over the course of the week. As it is important to understand the full context of the problems presented, all questions are valid and should be treated with respect. Since students are the focus of the ITT, they should be encouraged to lead discussions and

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present their own ideas, within a supportive environment. The colleagues from Bath had explained to me that as a teacher you have to trust the process above all: the students and scientists will develop project ideas together. It is not primarily the responsibility of the academics to make this happen. Within the set framework conditions, such as the time structures or the allocation to certain working groups, the team organises itself to a large extent – but as a teacher I have to be able to allow that.

HINT: So it really is learner-centred teaching. Can you imagine that such a format could also be transferred to other disciplines? In 2023, we want to start a larger initiative to network and promote transfer-oriented teaching or challenged-based teaching in the field of sustainability at Heidelberg University. Do you think that this format would also be suitable for this?

Winckler: As far as I know, the colleagues from Bath have had very good experiences with exporting the ITT format to the social sciences. It is important to analyse exactly how complex the questions have to be in order for this challenged-based workshop format to work. And you have to identify good collaboration partners from civil society. But with the Heidelberg Centre for the Environment (HCE), we have very good collaborators who also have an impact on civil society.

HINT: Can you give any other tips for people who want to try out, reproduce or adapt the format?

Winckler: Remember not to order too little pizza for the working groups! No, joking aside: openness, curiosity and committed partners. Otherwise, I'll say it with the colleagues from Bath: trust the process.

HINT: Thank you for the interview!

Das Gespräch führte Petra Eggensperger

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