IAMIT 2023

Implementation of Advanced Mathematics in Teaching

March 21 – 24, 2023

Englerstraße 2, Karlsruhe, Germany

Building 20.30, Room 0.014

www.scc.kit.edu/forschung/IAMIT2023.php

*Each **plenary talk** lasts 40 minutes + 20 minutes of discussion. Each **talk in a symposium** lasts 15 minutes + 5 minutes of discussion. After the last presentation of each symposium, we will have about 40 minutes to deepen the discussions related to the presentations of that symposium.*
Some speakers provided additional material. This material can be accessed here: https://bwsyncandshare.kit.edu/s/oQXSYiJCAEkZHpD (code: additional_material_IAMIT2023)

Tuesday, March 21st

Plenary talk

14:20 – 15:00

Good education for working in interdisciplinary STEM projects: Experiences and wishes – Martin Bracke (Kaiserslautern, Germany)

Abstract: For many years, stakeholders in politics and from various educational sectors have agreed that education in STEM subjects is particularly important in view of the major issues of the future, such as climate change and the use of artificial intelligence. It is becoming increasingly clear that training in individual STEM disciplines alone is not sufficient to achieve this. In recent years, therefore, serious work has been done to define the goals and content of STEM education - and the process is far from complete. In this regard, clarifying these important issues is a prerequisite for both expanding and adapting teacher education accordingly and aligning practical implementation in our schools and universities with emerging needs.

What about the necessary basics and desirable knowledge and skills needed in mathematical modeling - especially of complex interdisciplinary projects? Are these adequately addressed by existing educational programs? In this talk, I will provide a subjective review of the above questions, based on my experiences in many student projects, STEM classes in school, and numerous teacher

trainings. Afterwards, I will present my wishes for new or changed content regarding a good preparation to work in interdisciplinary STEM projects.

Plenary talk

15:30 – 16:30

Detecting Fake News and Learning More About Reality – a Very Important Part of Mathematics Education – Jürgen Maaß (Linz, Austria)

Abstract: Fake news are often used to manipulate people. Some of them are simple lies and easy to detect. Some are more elaborated. They use mathematical arguments (numbers, statistics, diagrams, models) to get more creditability. "Rational" politics is becoming increasingly difficult when a growing part of the population lives in various "reality bubbles" (that are generated and strengthened by Fake News) and an increasing number of people is less and less amenable to rational arguments. What can we as mathematics teachers (and experts for mathematics education) do about it? Of course, we can try to write counterstatements to all the Fake News that are spread. But it seems better to me if we follow the famous motto: "Give a starving man a fish and he will eat for a day. Teach him to fish, and he will never go hungry again!" Following this motto, let us try to empower people to recognize Fake News as such. Let's try to make the objectives "Education for maturity!" or “Empowerment for becoming critical citizens”, which are always prominent in the general teaching goals for all schools, actually and very concretely achieved in mathematics education in schools! What does this mean for mathematics education? Reality-based mathematics teaching, especially with its components "model criticism" and the already often thematized examples on the topic of "critically questioning statistics!" can and should definitely contribute to this! When we deal with different models of the same reality (especially those that are committed to opposing interests as is often the case in the field of ecology or economics) in school or university, we also open the door to philosophy: what actually is "reality"? To what extent does mathematics play a role in what we perceive or think we know as “reality”? This will help to understand mathematics, reality and us as individuals and as a society better.

Minisymposium 1

16:30 – 16:50

Talk 1: International contest to promote teaching and learning of mathematical modeling – Angeles Dominguez (Monterrey, Mexico)

Abstract: The need for students to broaden their view of mathematics through its use and applications comes naturally when modeling is incorporated into the curriculum. An exciting and motivating way to introduce modeling is through a contest. In this way, teachers and students get driven and find time to include in their classes mathematical modeling. For many years, mathematics competitions have focused mainly on individual participation and target high achievers based on

their ability to answer abstract mathematical questions and problems from various math areas. These competitions are highly motivational for students, who prepare for months to acquire speed and precision in their answers. It is important to mention that those competitions are not for all. Not every high school student has the knowledge, competencies, discipline, and willingness to embark on such a challenge, making these contests apt for a few ones. However, there is an international contest, The International Mathematical Modeling Challenge (IMMC), whose purpose is to promote the teaching of mathematical modeling and applications for high school students (https://www.immchallenge.org/). The contest has been established to promote educational change and is based on the belief that students and teachers need to experience the power of mathematics to help better understand, analyze, and solve real-world problems where mathematics is applied. Moreover, it fosters students' collaborative skills since they work in teams of up to four students from any high school level. In this presentation, I will present examples of students' collaborative work that are truly remarkable for their use of modeling and interdisciplinary approach.

16:50 – 17:10

Talk 2: The use of tv/film in mathematical modeling – **Roberto Guerrero** (Tijuana, Mexico)

Abstract: Capturing the attention and imagination of students, in particular in the STEM fields is a challenge, in particular in the fast pace world of social media. To aid in this endeavor we propose that the use of popular tv and/or film media could aid. In this work. We will present an analysis of shot video from the popular US TV show “The Flash”, a TV series based on the graphic novel series of the same name, and show how a physics and mathematical analysis can be made, as also the key points where the key points for instructor intervention can be made as to be used as mathematical modeling exercise.

Karlsruher Institut für Technologie

Wednesday, March 22nd

Plenary talk

09:00 – 10:00

Challenges for Mathematics Education in AI and Data Science era – Rolf Biehler (Paderborn, Germany)

Abstract: In the era of AI and Data Science, the goals and content of mathematics education must be reevaluated to better prepare students for a future increasingly shaped by these technologies. This includes addressing the ethical implications of their use, such as data privacy and algorithmic bias. AI and Data Science provide new and interesting examples of mathematical and statistical modeling, which can enhance traditional topics like calculus, linear algebra, functions, statistics, probability, and data analysis. However, a renewed emphasis is required on traditional topics, with an inclusion of predictive modeling and its components of training, testing, and evaluation data. Algorithmic models and thinking have gained importance, and multivariate and non-traditional data should be given more attention in statistics education. Classification problems, which are significant beyond the classroom, need to be included in curricula. Finally, determining which digital tools are appropriate for secondary classrooms to support students' learning and engagement with AI and Data Science is a crucial consideration.

Minisymposium 2

10:15 – 10:35

Talk 1: Decision trees with data cards in Grade 6 - Insights into the tool and the teaching module – Susanne Podworny (Paderborn, Germany)

Abstract: Artificial intelligence plays a major role in the everyday lives of many (young) people. Students interact on a daily basis with various applications (e.g. social media platforms, Youtube, Spotify, Amazon, smartphone camera, video games) that involve AI. There are also examples of AI use in socially relevant fields such as medicine and justice. Almost all AI applications that have been developed recently are based on data and data-driven machine learning methods but the associated methods are often not understood, even mysterious. In the ProDaBi Project, we developed a tool (data cards) and a corresponding teaching module that intends to convey basic knowledge about machine learning using the example of data-based decision trees. The topic is presented in an age-appropriate way, so that students can work with data cards as an unplugged tool in the context of nutrition. They can work mainly in an activity-oriented way on an interactive level, in order to understand the basic principles of data-based decision trees and machine learning. The teaching modules addresses among others the question “How can AI help us decide whether food is rather recommendable or not?“ Students’ performances in an assessment task and self-assessment show

that young learners can use a decision tree to classify new items and that they liked the corresponding teaching unit.

10:35 – 10:55

Talk 2: Artificial Intelligence and Machine Learning with Decision Trees realised with the digital tools CODAP and Jupyter Notebook for Mathematics and Computer Science Teaching – Yannik Fleischer (Paderborn, Germany)

Abstract: Data science and machine learning methods are increasingly being used in many areas of life, producing artificial intelligence applications that help shape all our lives. This development is now leading to these topics finding their way into German school curricula (e.g. North Rhine-Westphalia). One of the methods of machine learning that is particularly suitable for use in schools is data-based decision trees. Due to their hierarchical rule structures, decision trees are easy to interpret, making it possible to understand individual decision processes, but also to analyse patterns in the underlying multivariate data. Moreover, understanding an elementary decision tree algorithm does not require advanced mathematics. In the presentation, teaching materials and examples from the ProDaBi project (www.prodabi.de) will be presented to show how decision trees can be used in the classroom at secondary level I and II. Two different digital tools will be introduced. The digital tool CODAP focuses on the manual or semi-automatic creation and understanding of the structures of a decision tree, without requiring any programming skills from the students. Jupyter notebooks with the Python programming language also allow decision trees to be created automatically, which is a further or more in-depth option. These Jupyter notebooks can be used both menu-based (without any programming knowledge on the part of the students) and code-based with a higher programming content in the classroom.

10:55 – 11:15

Talk 3: How much mathematical modeling is in AI? – Martin Frank (Karlsruhe, Germany)

Abstract: I will try to argue that mathematical modeling, in the sense of a certain kind of mathematical thinking in an interdisciplinary context, is becoming ever more important in the age of digitalization, the data deluge, and artificial intelligence. It should therefore play a key role in education. I will try to outline how this could be achieved. I will also raise questions: How mechanical does mathematics education have to be? How much room is there for creativity? How to balance disciplinarity and interdisciplinarity? How to create awareness of the key role of mathematical modeling?

11:15 – 11:35

Talk 4: AI education as a starting point for interdisciplinary STEM projects? – Sarah Schönbrodt (Karlsruhe, Germany)

Abstract: Artificial intelligence (AI) is a key technology nowadays and of enormous relevance for our society. A central characteristic of applications and methods from the field of AI is that they are highly interdisciplinary. Both mathematics, computer science, and other STEM as well as non-STEM disciplines are crucial depending on the application at hand. In addition, ethical considerations play an important role. Thus, together with the increasing demand to bring AI education into schools, comes the opportunity to design and implement interdisciplinary projects. Using the example of human activity recognition on smartphones I try to show how interdisciplinary AI projects can be designed focusing on the mathematical aspects while incorporating knowledge from computer science and physics.

Plenary talk

14:00 – 15:00

IMMC-Spain: Introducing the modelling challenge in Spain – Irene Ferrando (Valencia, Spain)

Abstract: During summer 2019 I had the opportunity to discover the International Mathematical Modelling Challenge competition. Since there is a growing interest in Spain in the use of modelling in mathematics teaching in secondary education, I thought it might be a good idea to organise the competition in my country. Together with a team of collaborators, over the last three years we have managed to get more than 90 student teams to participate in the IMMC-Spain competition. In addition, each year, two teams have been selected to participate in the international competition. In this talk we will present the details of the organisation of the competition, emphasising the aspects that have been considered in the design of the problems posed. We will also discuss some aspects related to teacher training in the use of modelling in mathematics teaching.

Karlsruher Institut für Technologie

Thursday, March 23rd

Plenary talk

09:00 – 10:00

Mathematical modelling activities from engineering to school – Avenilde Romo-Vázquez (Mexico City, Mexico)

Abstract: A big challenge in our current era is to build relationships between mathematics used in engineering workplaces, including engineering research, to mathematics taught in the training of engineers. Some works trying to handle this challenge have been developed and framed in the anthropological theory of the didactic. The critical step is to analyse the mathematical modelling activity in engineering, elucidating the tasks and how engineers perform and justify them. Based on it, a didactic transposition is performed, and didactics devices are designed to permit the students to do a modelling activity closely achieved by engineers. To illustrate this, I will show examples of didactical activities designed and implemented and reflections on the achievements and limits of this approach.

Minisymposium 3

10:15 – 10:35

Talk 1: Patterns of interplay between the tool use and the learning outcome in projects about modelling with differential equations – Mette Andresen (Bergen, Norway)

Abstract: This presentation aims to start a continuation or sub section of my ongoing study of learning mathematics by modelling in the case of differential equations (DE). Data for the study is 26 group-reports from experienced mathematics teachers participating in a masters' program in mathematics education. When modelling authentic problems by DE, it is indispensable to include a variety of digital resources such as databanks and software for numerical solutions, graphical representations, and some sorts of simulations. Apps with simulations of commonly used DE models are widespread on the internet, some of them are very user-friendly and elaborated to a degree that justify use of the term ready-made tools. Textual analyses of the reports served to identify and shed light on relations between the tool in use, use of the tool, the DE model, the group's modelling strategy and their learning outcome. Previous results from the study indicate (among others) that familiarity with the tool and the capability and working style of the groups, rather than the tool itself, determine the learning outcome of the modelling project. The presentation gives the background for this result and encourages discussion of its implications for the design of teaching sequences including modelling. Finally, the direction for further analyses of data may be discussed as well.

10:35 – 10:55

Talk 2: Integration of STEM disciplines in an interdisciplinary course for first-year engineering students – Genaro Zavala, Angeles Dominguez (Monterrey, Mexico)

Abstract: Universities today face challenges such as the integration of a globalized world, the need for new skills in the labor market, new educational models after the pandemic, and technological advances that generate concerns in society regarding traditional higher education. During the last few years, our institution, a private multi-campus Mexican university, has been preparing for these new challenges by changing the educational model from traditional lecture-based to challenge-based learning with an emphasis on competency development and interdisciplinarity. Upon entering the School of Engineering and Sciences, first-year students take courses, with the main goal of introducing them to mechanics, electricity and magnetism, calculus concepts, mathematical modeling, programming, and algorithmic reasoning from an interdisciplinary perspective that combines physics, mathematics, and computer science. This talk presents the design of a course for first-year engineering students using challenge-based learning as an educational strategy. The design is based on competencies rather than learning objectives and builds on the How People Learn Framework and Legacy Cycle to integrate three different disciplines that are important in solving the challenge of an engineering context. We will also present how this course is implemented with faculty members from four different disciplines working with an interdisciplinarity perspective: physics, mathematics, computer science and engineering.

10:55 – 11:15

Talk 3: What role can differential equations play in upper secondary mathematics education? Modelling and qualitative analysis – Sebastian Bauer (Göttingen, Germany)

Abstract: Despite their central role in science and computation, differential equations tend to lead a marginal existence in school mathematics. In this lecture, a concept is presented that can be used to tap the potential of differential equations for meaningful modelling and reasoning tasks in the school context. The focus is on the one hand on the formulation and on the other hand on the qualitative solution of differential equations. First experiences from experimental settings will be reported.

11:15 – 11:35

Talk 4: Epidemiological modeling: A simple approach – Miguel Alejandro Díaz Hernández (Tijuana, Mexico)

Abstract: The transmission of a disease within a population is a classic problem in mathematical modeling using differential equations. The goal of this project is to introduce mathematical modeling to students using a phenomenon as common and as current as the transmission of an infectious disease using simple language to guide the students to the development and solving of the equations

involved. Initially only a very simple SI model will be used, but more complex models could be introduced in the future.

Plenary talk

14:00 – 15:00

Implementation of interdisciplinary STEM projects in school and university with suggestions for changes in the educational system – Martin Bracke, Luis Siero, Sarah Schönbrodt

Abstract: First, we present different ways of conducting interdisciplinary STEM projects in school and in engineering education at university, where mathematical modeling (and thus mathematics) plays a key role. We then try to identify some common success factors and requirements that, in our experience, are important for the implementation of good projects. Finally, this leads to suggestions for additions and also changes to the current form of STEM education in schools and universities. Here, we refer both to mathematics/MINT teaching in schools and specifically to the education of future teachers. In the end, we can build a bridge from Tuesday's plenary talk to experiences with and aspirations for the current education system.

15:30 – 15:50

Insight into CAMMP material – Stephanie Hofmann (Karlsruhe, Germany)

Abstract: Within the Computational and Mathematical Modeling Program (CAMMP, www.cammp.online/english) located in Karlsruhe and Aachen we aim to let students work on real-world, authentic, and relevant problems from everyday life, research, or technology. In this talk I will present the main activities within CAMMP and show interactive, digital teaching and learning material for the use in mathematical modeling days with high-school students.

15:50 – 17:30

World Café + Open Work Session

All participants are invited to bring a) teaching and learning material, b) results from students or c) further interesting material that can be explored by the other participants during this session.

Karlsruher Institut für Technologie

Friday, March 24th

Plenary talk

09:00 – 10:00

A brief overview of 20 years of methodological and theoretical developments in the research on Fermi problems in the context of teaching and learning mathematical modelling – Jonas Bergman Ärlebäck (Linköping, Sweden)

Abstract: This presentation provides a brief review of the research done on Fermi problems in the context of the teaching and learning of mathematical modelling. Generally, Fermi problems can be characterized as open, non-standard problems that require the students to make assumptions about the problem situation and estimate relevant quantities before engaging in often simple calculations. The overview focuses on different used and developed methodologies and frameworks in this area of research over the last 20 years. In particular the connections between Fermi problems and aspects of the teaching and learning of mathematical modelling will be discussed and highlighted.

Minisymposium 4

10:15 – 10:35

Talk 1: Combining analysis tools to characterize mathematical model development in statistical tasks – Lluís Albarracín (Barcelona, Spain)

Abstract: The objective of our work is to characterize the modelling activity of high school students, as well as the mathematical models elaborated by them when faced with a statistical modelling task. The task implemented in the classroom places special emphasis on the concept of dispersion. Thus, our analysis wants to verify that this activity really creates in the students the need to quantify the difference given in a real distribution of statistical data. For this, we use two analysis tools in combination. The first is the Modelling Activity Diagram (MAD) (Ärlebäck, 2009). These diagrams allow us to analyze the modeling cycle from time graphs in which the specific modeling activities that the students are developing are represented. In our study, we incorporate the theoretical framework of solving statistical problems (Arnold, 2021) given the characteristics of the proposed task and the students (4th of ESO, 16 years old). At the same time, we represent the mathematical models that students, working in groups of four, create throughout the modeling process. For this, we use diagrams of representation of mathematical models (Albarracín, Aymerich & Gorgorió, 2017) in which the concepts and procedures that shape the model at each moment of the resolution are explained. All this with the final objective of studying the evolution of the models throughout the process to be able to influence the episodes where this model is developed, generated, or changed.

10:35 – 10:55

Talk 2: Agent based modelling in mathematics education – Nataša Grgurina, Jos Tolboom (Groningen / SLO, Netherlands)

Abstract: Models and modeling are considered essential to learning science. In the Netherlands, the new secondary mathematics curriculum currently being developed is expected to address modeling. The likely learning objectives will concern modelling and research cycles, the construction, analysis and use of models, and using ICT to do it. Models can appear in various forms: as narratives, drawings, differential equations or computer programs. The latter are executable and can be used for simulations and thus (scientific) experiments. Agent-based modelling (ABM) allows for the construction of computational models of complex systems, surpassing the possibilities of mathematics alone, while requiring limited mathematical skills. Rather, the actions and interactions of the actors in the system are described algorithmically. The simulations with ABM models can generate data which can be subjected to (statistical) analysis. In my research, I explored the pedagogical aspects of teaching ABM with NetLogo in a secondary CS course. Starting with the mathematical modelling cycle, I defined the computing modelling cycle where the model is a computer program. The students constructed and used models of various phenomena from other disciplines which provided context, while the focus lay on the construction of valid computational models. The results suggest that computational modelling could (and should) get a prominent place in other subjects: in mathematics as well as other (STEM) disciplines.

10:55 – 11:15

Talk 3: Computational Thinking in Secondary Mathematics Education using GeoGebra: Results from a Design Study – Christos Chytas (Netherlands)

Abstract: Nowadays, mathematics teachers in K-12 strive to promote their students' mathematical knowledge and computational thinking (CT) skills. There is an increasing need for effective CT-embedded mathematics learning material and a better understanding of students' perceptions towards them. In this work, we present the results of a design study, which included the design of a six-lesson learning activity aimed at fostering 16-to-17-year-old secondary students' CT skills in calculus lessons using the dynamic mathematics software GeoGebra. Our goal was to investigate how students perceive the integration of CT into calculus lessons with GeoGebra and what challenges they face in successfully completing them. We collected and analyzed data from students' code in GeoGebra, workbooks, semi-structured interviews, and questionnaires. Our findings suggest that most students mastered using CT concepts in calculus activities to a satisfactory degree and could reason about their computational solutions using GeoGebra and the generated graphs. Overcoming mathematical content knowledge gaps was essential to complete the lesson series successfully. Our study shows that students appreciate our CT-embedded calculus

lessons and GeoGebra's exploratory approach to mathematics problems, when provided with appropriate support. We conclude that an integrated approach to mathematics education and computational thinking is viable and might contribute not only to fostering CT but also to increasing interest in mathematics.

11:15 – 11:35

Talk 4: The effect of programming on mathematics education – Lukas Bayer (Kaiserslautern, Germany)

Abstract: Programming is widely used in applications across engineering, technology, nature sciences and mathematics as a tool. As such approaches to STEM education should consider if and how to implement programming into the curriculum and how it will effect the different disciplines themselves as well as their interconnections. With countries like Sweden implementing programming as part of the mathematics curriculum, it becomes particularly interesting to look further into the effect of programming on mathematics education ranging from different implementations into the curricula and their effect on the development of mathematical skills to the possibly transformative influence of programming on mathematical modelling itself. In this minisymposium I want to give a brief overview of and motivation for the research of programming in mathematics education and discuss different topics that would be interesting for further research.