

BRIDGING THE GAP: A PEDAGOGICAL TOOL FOR TEACHING MATHEMATICAL MODELING WITH SPREADSHEETS

Dávid Paksi¹⁾, Márk Csóka¹⁾, Szilárd Svitek²⁾

¹⁾Department of Informatics, J. Selye University – Komárno (Slovakia)

²⁾Department of Mathematics, J. Selye University – Komárno (Slovakia)

Abstract. The widespread use of information and communication technologies (ICT) offers new opportunities in many topics of mathematics education. As science and technology are constantly evolving, information technology is becoming increasingly intertwined with education. Modeling, simulation and visualization are already proven methods in teaching subjects such as physics, chemistry or engineering. These methods can help students see connections more clearly and develop their creative thinking. This paper aims to further explore this direction in the field of mathematics education, with focus on differential equations. We chose spreadsheets as our tool to calculate and visualize the processes described by differential equations. We demonstrate a wide range of applications of differential equations through real-life examples, such as in modeling physical, biological, and economic processes. This method provides students a better understanding of the practical usefulness and applicability of these equations. The study thus shows how integrating ICT into mathematics education can help students gain a deeper understanding of the underlying mathematical concepts and improve their mathematical thinking and problem-solving skills. ICT tools enable teachers to use interactive and engaging teaching methods, resulting in an exciting and practical education for students. This paper outlines the potential of ICT in mathematics education, with a focus on the use of spreadsheets for modelling and visualization. It highlights the benefits of integrating technology into the classroom to enhance student learning and engagement.

Keywords: mathematics education; spreadsheets; differential equations; interdisciplinary education; advanced uses of ICT; real-world problems

1. Introduction

This study is an extended version of the previous conference paper which evaluates the usability of spreadsheets in education. In this paper we narrow our focus to differential equations aimed to support mathematics education by using ICT technologies to solve otherwise complex problems addressed by

the field of modeling (Paksi et al., 2022b). The prepared teaching tool is available online¹.

This study is primarily aimed at undergraduates, especially those who are open to new methods and technologies. Integrating ICT into mathematics education offers significant benefits: it provides modern, interactive and illustrative teaching methods that help students understand theory and apply it in practice. In university-level education, traditional methods are often unable to arouse students' interest or deepen their knowledge. New teachers can particularly benefit from incorporating these innovative tools into their workflow, as they can convey complex mathematical concepts in a more efficient and motivating way. Such approaches not only develop students' problem-solving skills, but also introduce real-life applications of mathematical modelling.

The development of science and technology brought changes to the whole world. Information Technology (IT) is no exception either. Over the past few years the repertoire of available digital tools expanded and they also caught up in education (Oleksandr et al., 2023). At the same time the mentioned advancement raised the stakes: the required digital skills to master for general computer literacy are diverse.

To train people who successfully overcome modern challenges we must pay attention to the content of education and its presentation (Talhafer, 2017).

In the field of education, IT has gradually become indispensable in the last decade (Rodriguez-Jiménez, 2023). The shift towards remote learning and the need for digital solutions further increased its importance. With the aid of IT, education can go on without significant interruptions in the digital space. It became essential to devise methods for instructing specialized subjects like physics, electronics, and chemistry. Fortunately, a solution was already in existence before the demand arose, as the field of modeling and simulation had been a researched discipline for quite some time.

There are many tools available for teaching mathematical models, but most of them require the usage of high-level programming language. The usage of Excel for teaching natural sciences is crucial because provides an opportunity for students to develop skills in data analysis, modeling, and scientific thinking (Pohoriliak et al., 2023).

Spreadsheet applications have a relatively long history and their usage often constitutes part of computer (and digital) literacy. Computational thinking (CT) surfaced as part of digital literacy and is mostly described as a problem-solving approach imported from computer science. CT got attention over the years because the skillset it promotes is universally usable (Borkulo et al., 2023). Hence, the task at hand was for educators to develop and refine the necessary tools, experiments, and teaching materials, making them available for educational purposes (Svitek et al., 2022).

A common feature of similar educational tools is that they all require a strong mathematical background to be effectively applied and to support deeper understanding of students (Serra & Godoy, 2011).

Today, crafting educational tools remains a challenging endeavor. It may seem logical that everyone can access the same content since most people have a computer at home. However, the reality is more intricate. To ensure access to the same content, individuals must be able to access the relevant digital environment. This may entail installing specific software, while in other cases, merely having a web browser suffices. When it comes to the former situation, the software can either be paid or free. If it demands high performance, users may encounter factors that disturb the user experience or even prevent access to the content. This is particularly relevant in the context of modeling and simulation, and from an educator's perspective, such barriers are unacceptable.

Public education systems typically prefer solutions that are freely accessible to all (Paksi et al., 2022a). Several companies have longstanding commitment to supporting education. Spreadsheet applications are part of the curriculum and widely used for various tasks in the labor market. In Slovakia, the Microsoft 365 software suite, including the aforementioned member of the software family, is available free of charge for educational purposes. In recent years, the emergence of Google Suite in educational institutions has diversified the range of tools used and made it more difficult to develop out of the box, platform-independent learning materials. Thus, the primary challenge remaining for educators in higher educational institutions (HEIs) is to adapt the teaching material to effectively facilitate the teaching of modeling simulation and visualization (MSV).

2. Pedagogical approach

We define methodological approach as a set of ideas, principles related to the nature of learning along which the educational process is implemented. The term pedagogical methodological approach covers the ideas about teaching and learning. The goal of pedagogical methodological approaches is to maximize the success of the educational process. It is not unique that different educational institutes and teachers combine multiple approaches during teaching sessions (Harizanov, 2023). This is necessary to meet the needs of the specific blend of students and the curriculum at the same time. Nowadays teachers can choose from multiple approaches, for this study we used and combined the problem-based learning, deep learning and interdisciplinary learning approaches.

Problem-based learning (PBL) is a pedagogical approach that has emphasis on theoretical foundations. It is an instructional method, where students are presented with an open-ended question or a real-world problem. The primary objective is to systematically gather information, develop a viable solution, present their results and express their own insights related to the topic. The chosen problem must be carefully selected to invite the students on a journey to carry out their own research, organize and evaluate the collected information. In PBL, the educational roles have undergone changes: the teacher assumes a mentoring role to guide students during their research, while students gain a prominent role in the problem-solving process. The PBL relates to a particular context and situation by engaging participants in the processing of authentic scenarios as opposed to abstract theoretical constructs (Csóka & Czakóová, 2021; Tempelmeier, 2016).

Deep learning utilizes understanding and thinking as the method's main pillars. It is characterized by thorough understanding of the fundamentals of the subject matter accompanied by critical thinking and the ever-promoted problem-solving of IT. The mentioned core competencies are complemented by collaborative work, communication, and the autonomy of one's own learning. Such learning can help cultivate positive beliefs and attitudes about oneself which provides motivation for continuous learning (Marton & Saljö, 1976a; Marton & Saljö, 1976b; Csoka et al., 2022).

Interdisciplinary learning is a pedagogical approach that draws a wide variety of perspectives from diverse academic disciplines. It not only

introduces these viewpoints in the learning environment but also requires that collaborative tasks actively share, discuss, and integrate them. Interdisciplinarity is essential to solve complex, real-world challenges that draw from multiple science fields and also demand expertise. By directing students' attention to a particular problem or topic while exploring it through the perspective of multiple disciplines helps them to organize their knowledge their own way and supports their comprehension of their own intellectual maturation. Moreover, exposure to interdisciplinary learning can foster critical thinking and metacognitive skills (Zhu & Burrow, 2022).

3. Implementing MSV at a glance

The making of mathematical models is the process of encoding and decoding reality, in which a natural phenomenon is reduced to a formal numerical expression. There is an essential difference between the mathematical model and the laws of physics. The first is a representation of a particular system in mathematical terms, while the second is a general statement based on a physical theory. Modeling, simulation and visualization (MSV) are all tools that help the user better understand, predict, test and optimize real-world systems and processes without having to work directly with the real system. The first step in the process is to create the mathematical model. We set the parameters required for the model according to our best knowledge, then run the simulation to imitate and reproduce the behavior of the real system (Meng et al., 2020). After that, we evaluate the results. If they meet the defined expectations, we have reached the end of the process, otherwise we examine whether the mathematical model was correct, or if the parameters need to be adjusted.

3.1. Role of MSV in education

MSV plays a useful role in teaching mathematics and science subjects (Bilbokaite, 2016), as it allows students to gain a deeper understanding of abstract concepts and phenomena (Niazi & Temkin, 2017). These pedagogical tools help students not only to interpret knowledge as passive recipients, but also to become active participants in the learning process. One of the main advantages of MSV is that they provide concrete and tangible examples of mathematical and other scientific principles. Borba also states that many processes and concepts can be tied to visual

representations, which can be built to help the understanding of the hidden mathematical structure (Borba, 2005). In this way, mathematics and scientific knowledge do not remain at the level of abstract theories but can also introduce their application in real life.

Creating models requires students to analyze phenomena, form associations, derive algorithms, test and reformulate hypotheses. Modeling is particularly useful in constructivist learning environments where students explore, experiment, create, collaborate and reflect on real-world problems. MSV also helps students to connect theoretical knowledge with practical application. For example, when a student calculates the velocity (including air resistance) of a free-falling body, or simulates a chemical reaction, they apply their theoretical knowledge to a real problem. In this way, one will experience how the concepts and formulas learned can be used in real life, resulting in motivation and deeper understanding. In addition, modeling and visualization help students develop their critical thinking and problem-solving skills (Smirnov & Bogun, 2007). The visualization provides an opportunity for students to experience the process. For example, in the case of this study, differential equations are given a form that is easy to interpret even for laics, thus promoting a deeper understanding of the topic (Csoka2021a; Svitek et al., 2022). When a student analyzes a complex model, they employ a set of skills related to computational thinking: logical- and algorithmic thinking, information processing, recognition and solving of subtasks. These skills are useful not only in mathematical and scientific fields, but also in other areas of life.

3.2. The information and communication technologies in mathematics education

Information and Communication Technologies (ICT) are processes, methods and laws related to the recording, analytical-synthetical processing, storage, retrieval and dissemination of scientific information (Mikhailov et al., 1966; Wellisch, 1972). The goal of ICT is to make the mentioned processes more effective, safe and easy to use. The use of ICT plays an increasingly important role in the teaching of various educational subjects. Such development cannot be attributed alone to the overwhelming use of digital tools, but one must acknowledge that ICT is capable of transforming and enriching education in ways that match with modern pedagogical goals. ICT

has the potential to spark students' scientific interest and engage them (DeWitte & Rogge, 2014). The use of these technologies increases the interactivity and enjoyment of learning (Bowers & Berland, 2013) and can be a tool for bridging the ever-growing gap between mathematics and other subjects (Jehlička & Rejsek, 2018).

Interactive learning environments, simulations and online labs allow students to experiment and practice without exposing themselves to real world risks. This way aids students in developing a deeper understanding of natural sciences and encourages curiosity and discovery. In addition, the digital space makes it possible to model and observe events that would not be possible in real life due to lack of time, financial background, resources, too large-, small scale or are simply too dangerous. Furthermore, ICT helps learners to connect what they have learned (theory) with lifelike problems, situations, events (practice). For example, in mathematics and physics they can use software and computer modeling to understand abstract concepts and apply them to solving real-world problems (Oliveira & Nápoles, 2017). In this way, students experience the practical application of the knowledge acquired during learning, which should be the goal of the whole teaching process.

3.3. Spreadsheets in education

Spreadsheets represent a group of application packages used for tabular calculations. Spreadsheets are inexpensive, can be run on machines with low-end specifications, and are widely used by companies, institutes, and all levels of education. In addition, introduction to spreadsheets is part of the general IT curriculum (Arganbright, 1993).

In general, students can support their ideas with numbers and graphs, or keep a record of daily activities using spreadsheets (Abramovich et al., 2010). However, not many people use spreadsheets in the classroom to draw new conclusions about a topic, since spreadsheets are usually not developed with the intention of provoking new ideas or creating an environment of debate. Depending on the topic, spreadsheets like Microsoft Excel can be involved in high school education on a basic level, and in HEIs for more advanced tasks and topics.

Spreadsheets are present virtually everywhere in today's engineering field: from elementary numerical analysis in the general engineering field to

software quality control, cache-based parallel processing systems in the electrical industry. Spreadsheet simulation models can be used as a platform to understand the mechanisms behind a discrete event, as well as for system dynamics approaches. Their advantages include gaining software knowledge in a short period of time, wide availability and smooth usability (Skafa et al., 2022).

3.4. The interdisciplinary role

The use of mathematics in interdisciplinary education (IE) can provide various scientific and pedagogical benefits, states (Jehlička & Rejek 2018). This approach connects mathematical thinking with other disciplines and real-world problem-solving situations, which expands students' cognitive and intellectual skills. Interdisciplinary education allows the integration of mathematics with the help of computer science into other disciplines such as computer science, physics, biology, engineering, i.e. STEM areas (Doig & Jobling, 2019). As a result, students gain a broader perspective and can see the relevance of mathematical principles and methods to real life and other disciplines. This improves general knowledge and scientific literacy.

An interdisciplinary approach fosters problem-solving ability and critical thinking. Students encounter complex problems that are not limited to just one area or subject but involve knowledge from several diverse disciplines of different educational levels (Lucas et al., 2019). As a result, students must use different approaches to solve problems. It is expected that this process helps to develop their creativity and analytical skills. In interdisciplinary education, the application of mathematical principles and methods to real problems creates real value. Students learn how to use mathematics via real-world examples, such as cooling a tea, the spreading of cancer cells, financial decision-making, data analysis, environmental protection, and more. This practical applicability helps to transfer knowledge to real life.

4. Process of implementation

Differential equations are mathematical tools that can be used to model changes and processes in specific systems. Differential equations are useful in many scientific fields, such as physics, modeling chemical reactions, analyzing biological systems, describing economic processes, and many other applications. One of their most important features is to describe the

relationships that govern changes over time in a system. So, if we are interested in how the parameters of a system change over time or how the properties of a particular system change in a particular area, we can model these processes using differential equations. Differential equations also play an important role in scientific research and engineering practice. With their help, the behavior of different systems can be predicted, analyzed and optimized. In addition, they can solve complex problems that would be difficult to deal with other methods.

4.1. Continuous models

By continuous models we mean continuous state and continuous-time differential equations, which can be classified as members of the Differential Equation System Specifications (DESS) group (Zeigler et al., 2018).

Differential equations are a common means of describing natural, technical, and economic processes, i.e., continuous mathematical models are often possible to describe with their help. The theory of Ordinary Differential Equations (ODE) deals with the study of such models among others. These studies focus primarily on the solving of different types of tasks, primarily examining the conditions under which the task will be correctly set. It is rarely possible to produce a solution in a closed form (i.e., to specify it using formulas that contain known and easy-to-evaluate functions). Therefore, from a practical point of view, an approach in which we seek the solution in an approximate form with the help of some numerical method is unavoidable. These methods allow us to produce a numerical solution with high accuracy and reliability (Atkinson et al., 2009). For differential equation models, a derivative function is used to specify the speed of change in the status variables. At any given time of the time axis, for a given state and input value, only the speed state changes are known. From this information it is necessary to calculate the state that will occur at any time in the future.

When we want to express this in the form of an equation, we need a variable that represents the current state. In our case, it is represented by the $z(t)$ state variable. The current input $u(t)$ indicates the speed at which the actual content is changing, which is expressed by the equation

$$\frac{dz(t)}{dt} = u(t)$$

where output $y(t)$ is equal to the current $z(t)$ state. By further, shaping the equation, we can get the classic ODE state equation representation:

$$\dot{z}(t) = f(z(t), u(t))$$

Most continuous-time models are actually described (or converted) in the form of an equation that does not give an explicit value to the state $z(t)$ after a certain period of time. Thus, in order to get the state trajectories, the ODE must be resolved. The problem is that obtaining a solution to the equation is not only exceedingly difficult, but in some cases, impossible. Very few ODEs have analytical solutions in the form of known functions and expressions. This is the reason why ODEs are usually solved with numerical integration algorithms that provide approximate solutions (Zeigler et al., 2018).

4.2. Explicit Euler method

Let $[a, b]$ be the interval, where the initial value problem $\dot{y} = f(t, y)$ solution must be found, where $y(a) = y_0$. Instead of searching for the solution of a differentiable function, which satisfies the initial problem $\{(t_i, y_i)\}$ set of points are generated and these points are used for approximation, where $y(t_i) \approx y_i$. To determine the set of points that approximately satisfy the differential equation, we first select the abscissas of the points. For simplicity, we divide the $[a, b]$ interval into M equal parts and select the mesh points (Mathews & Fink, 1999): $t_i = a + ih$ and $i = 0, 1, \dots, N$, where $h = \frac{b-a}{N}$.

The value h is the step length. Next, an approximation can be given for the differential equation.

$$y' = f(t, y) \quad [t_0, t_N] \text{ where } y(t_0) = y_0.$$

The standard Euler-method can be written as follows:

$$t_{i+1} = t_i + h \quad y_{i+1} = y_i + hf(t_i, y_i), \quad i = 0, 1, \dots, N-1$$

The above described can be easily translated into an algorithm (see Listing 1), that determines the substitution values of the chosen differential equation at an arbitrary interval in fixed steps.

It is important to mention that there are many other ways to prepare the previous algorithm. The first feature of the algorithm we created is that it

will not determine the values on the interval set by the user, instead extending to a maximum 1 step larger from the right limit.

Listing 1: Pseudocode for Explicit Euler method

```
Input: a, b, y0, h, f
  a - Initial time
  b - Final time
  y0 - Initial value
  h - Step size
  f - Function
begin
  y(1) = y0
  t(1) = a
  i = 1
  while t(length(t)) < b
    y(i+1) = y(i) + h * f(t(i),y(i))
    t(i+1) = t(i) + h
    i = i+1
  end
end
Output: t, y
  t - Time array
  y - Value array
```

4.3. The examined platforms

The User Interface (UI, see fig. 1) consists of two main parts: on the side down the user can set the initial values (I) the specific values (II) related to the exact problem to be modeled and the equation (III) itself, while the other part contains a XY Scatter chart showing the results. The initial values are the following: model simulation start time, model simulation end time, initial value and the step size expresses the detailedness. The problem specific values are model dependent and vary by each model, therefore they must be specified manually. These values have further usage because the model-specific equation resides in (III). The results of the actual model are shown

here, but the values regarding each step are saved to a separate worksheet. These values are later presented on a chart.

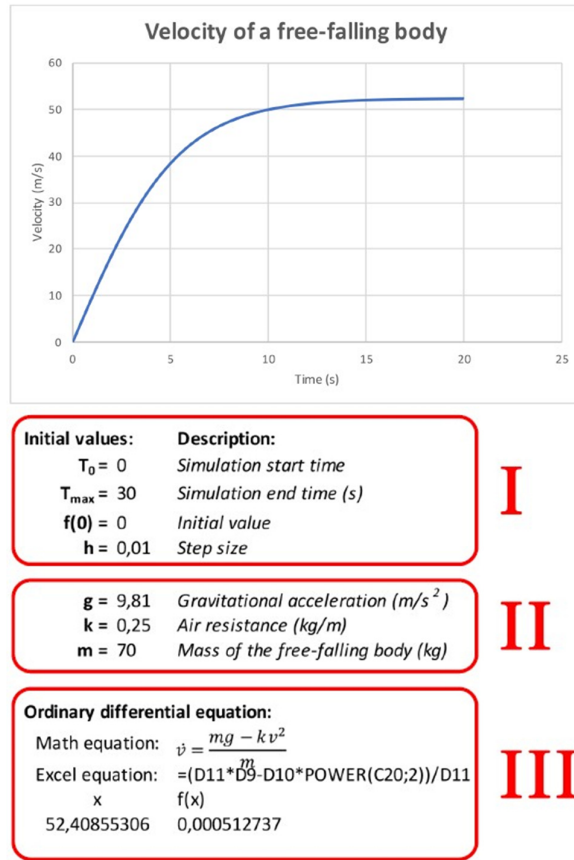


Figure 1. The UI (user interface) realized in Microsoft Excel

The corresponding values of each step calculated by the VBA (or Apps) Script are saved to a worksheet named “Data” (Paksi and Csóka, 2023). These values are necessary for creating the visual representation of the model. Due to the increased popularity of G Suite in education we considered it important that the introduced method should work with multiple applications. Microsoft Excel uses VBA programming language for

automation and macro creation, while Google Sheets utilizes their own Google Apps Script for similar functionality. Depending on the target application the above presented pseudo code (See Listing 1) can be easily localized for the target application.

5. The established curriculum components

In the following section we refer to each model as a teaching unit because the introduction, explanation, creation and reflection of one model can easily take up the 45-minute standard lesson time.

5.1.Problem: Emptying a liquid-filled tank (Zeigler, Muzy & Kofman, 2018)

Grade Level: 6th to 8th Grade of elementary

school Subject: Science and Mathematics

Learning Objectives:

- Students will understand the concept of the problem,
- Students will apply mathematical skills to measure and calculate (with their basic skills) the problem,
- Students will work collaboratively in groups to design and conduct experiments.

The teacher begins the lesson by presenting the problem and discussing the importance of it (e.g. predicting flooding or water usage). The students will work in groups to investigate the problem. At least two types of groups are needed: those who create and measure the actual situation, and those who do the modelling with the spreadsheet and analyze the results. It is possible and even recommended (especially for the accuracy of the measurements) to create multiple instances of each group type. After the students are done with the experiments and modelling (fig. 2), the teacher should:

- ask each group to share their findings,
- gather the students back as a whole class,
- discuss the factors that may have affected the experiment,
- guide the students in interpreting the results and drawing conclusions,

- encourage students to think about how this knowledge can be applied in real-life situations.

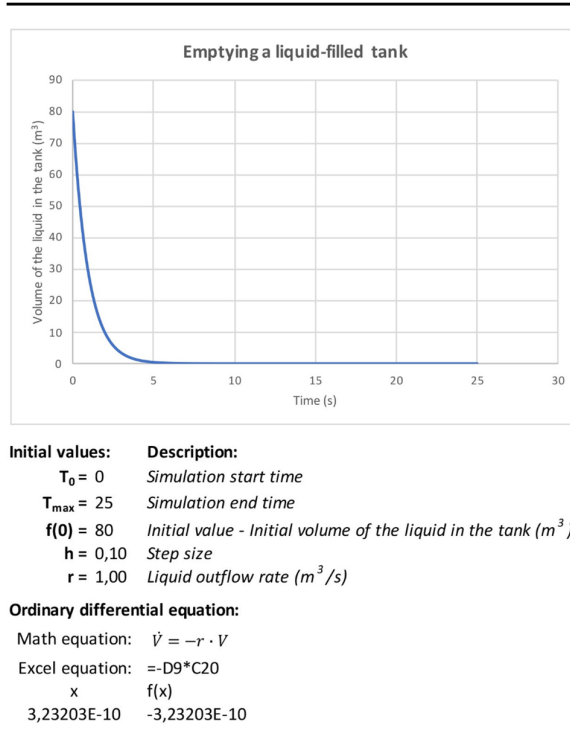


Figure 2. The simulated model for emptying the tank

In the spirit of spiral method of teaching mathematics and informatics in high schools, the same problem can be revisited in later school years. By doing so the formulas behind spreadsheets can be analysed in computer science lessons with a more complex approach.

5.2.Problem: Cooling a hot beverage

In grammar schools, such use of spreadsheets can be beneficial in several different lessons, thus forming stronger interdisciplinary connections. For example, in computer science classes, students could get to know the

functions used for programming better, while in STEM subjects, individual models help to understand the presented problems more deeply and more easily (Kézi, 2023).

In physics class, the fig. 3 model can be used to illustrate the given problem, and students have the opportunity to experiment with the given values, i.e., what happens when cooling tea under different parameters. The same model should also be incorporated into math lessons, for example in function analysis. Thus, students encounter the same model in several lessons.

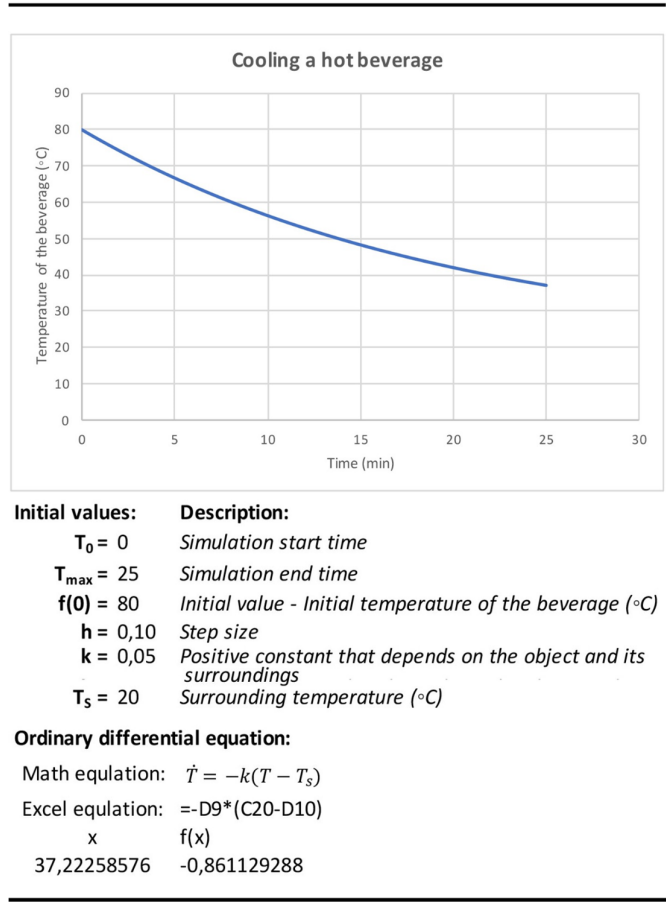


Figure 3. The simulated model for cooling a hot beverage

5.3.Problem: Spruce Budworm Model

Most species of spruce budworms are pests that destroy coniferous forests. Eastern spruce budworms’ diet mainly consists of spruce and balsam firtrees in the United States and Canada. The ecological dynamics of these outbreaks have been described using mathematical models that focus on the pest (spruce budworms), host (trees) and the worms’ main predator (birds) groups. A simple model describing the budworm population size over time can be built using the logistic growth model (Moghadas and Jaber-Douraki, 2018).

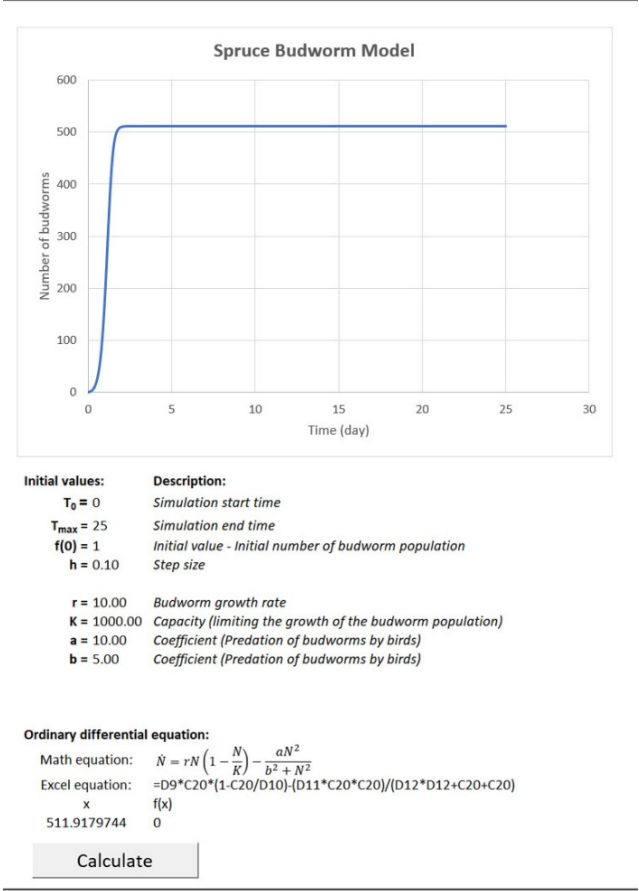


Figure 4. The simulated model for the budworms in the wood

For undergraduate students who have dealt with differential equations during their studies, prescribing and calculating ODE should not cause any particular problems. We can formulate the ODE based on the given parameters and the problem's model is given by **Error! Reference source not found.**:

$$\dot{N} = rN \left(1 - \frac{N}{K}\right) - \frac{aN^2}{b^2 + N^2}.$$

Consider the following realistic parameters:

- $N(t)$: The number of budworms in the spruce at time t .
- r : Grow rate of the budworm population.
- K : Carrying capacity (limits the maximum population size of the budworms)
- $\frac{aN^2}{b^2+N^2}$: Rate of predation of budworms by birds.

This model combines logistic growth and predation, considering limited resources and the effect of population density. The first term $(rN(1 - \frac{N}{K}))$ model's growth and the second term $(\frac{aN^2}{b^2+N^2})$ model's negative effects (such as predation) as the population size increases.

6. Discussion and implications

We examined the applicability of the developed teaching tool within school environment, as well as its pedagogical value, based on feedback from practicing teachers. The investigation was conducted within a qualitative research framework, as our aim was to achieve a deeper, contextually grounded understanding (Creswell, 2013).

As a first step, we reached out to in-service teachers who expressed openness to testing the teaching tool and subsequently shared their experiences in semi-structured, in-person interviews. From the pool of applicants, we selected participants based on their professional background and motivation. Ultimately, four teachers, each specializing in different subjects (physics, mathematics, and computer science) – met the predefined criteria. The interviews were subjected to content analysis, through which several recurring themes, experiences, and challenges emerged.

According to the interviewees' feedback, the application of the teaching tool yielded several pedagogical benefits:

- Increased student motivation and engagement: Students reported enjoying the opportunity to conduct their own experiments, even if these were carried out in a digital space rather than physical format. Analyzing the results of the experiments using spreadsheets encouraged autonomy and active participation.
- Interactivity and visualization: Differential equations and other abstract mathematical concepts became more comprehensible using interactive charts. Visualization supported understanding and contributed to an experiential, meaningful learning process.
- Integrability into classroom practice: The tool did not require the adoption of a new platform or advanced technological knowledge – familiarity with Excel or Google Sheets was sufficient for its use. This enabled students to repurpose their existing software skills for educational purposes.
- Interdisciplinary potential: Several teachers emphasized the tool's usefulness in interdisciplinary projects (e.g., blending computer science, mathematics, and biology), as it facilitates both modeling and interpretation across diverse subject domains.

Despite the advantages, several limitations and critical remarks were identified regarding the use of the tool:

- Lack of technological infrastructure: Not all classrooms are equipped with a sufficient number of computers or tablets, particularly during lessons in the natural sciences.
- Variations in digital competencies: Proficient use of Excel is not self-evident for all teachers and students, which may limit the full utilization of the developed tool.
- Limited range of models and creative space: In its current version, the tool offers only pre-designed models. Creating new models is more complex, which reduces students' opportunities to engage in the creative aspects of the modeling process.
- Challenges in interdisciplinary collaboration: Although the tool lends itself to interdisciplinary applications, the current structure of the education system offers limited support for cross-subject collaboration.

- Generational differences: Our experience suggests that older teachers were generally less open to trying the tool, highlighting a broader challenge in integrating digital tools into teaching process.
- Depth of understanding not guaranteed: While the tool can make abstract concepts more “playable”, this does not necessarily result in a deeper conceptual understanding.

ICT tools not only broaden the means of access to information, but also increase the quality and efficiency of education. The interactive, practical and global approach enables students at all levels of education to find real-world interpretations of science subjects. It promotes the development of critical thinking and problem-solving skills that they will need in future academic and workplace challenges. The use of ICT tools is therefore not only a modern trend, but an essential tool for developing scientific knowledge and computer literacy. Modeling and visualization help us understand and remember the curriculum more easily. The human brain tends to memorize and understand images and diagrams better than textual information. Therefore, using visual tools helps students to learn and memorize the educational material more effectively (O'Bannon et al., 2006).

Overall, teaching interdisciplinary mathematics (whether in primary or secondary school, or even in some areas of higher education) contributes to the broad development of students and prepares them for successful participation in a complex and dynamic world. The tool has been developed with this goal in mind, and its usage should be considered for the same reason. In our research, we examined the educational possibilities of modelling, how we can bridge the gap between mathematics and other science subjects. We chose spreadsheets as the modeling tool, as it is more user friendly and better known among students than MATLAB or other symbolic algebra software (Lim, 2006).

Finished simulations are those that exemplify a certain mathematical concept or relationship with dynamic data. The users' task is to change certain parameters in a fixed scenario to get the results produced by running the model. However, changing only certain parameters to understand a mathematical context or a mathematical concept can be considered as a form of passive participation without excessive interaction (Karakirik, 2015).

Although ICT tools enable interactive learning and realistic modelling, not all students and educational institutions have the adequate technological infrastructure and access. Thus, the use of ICT tools in mathematics education may cause disadvantages for some students and create inequalities in education. In contrast, spreadsheets are widely available and can run on most consumer-grade computers. By using spreadsheets for modeling, students may be able to gain a deeper understanding of abstract concepts and relationships, however the level of active participation and creativity may vary. Passive data entry or changing parameters does not always ensure full interaction of students with the learning process. This limitation is recommended to be considered when developing interactive learning environments. The implementation of interdisciplinary education is not always easy: cooperation between educational institutions and teachers, as well as the development of interdisciplinary curriculum, can present challenges, such as the parallel teaching of interconnected topics. In addition, it is important to properly train and support teachers in this type of education.

Our future plans include a full qualitative and quantitative study of the developed tool, tested in classrooms, to obtain verifiable results on its didactic effectiveness.

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NOTES

- 1) Paksi, D., Csoka, M., 2023. *MSV-ODE-Spreadsheets*.
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✉ **Dr. Dávid Paksi, Assist. Prof.**

ORCID iD: 0009-0009-2066-9389
Department of Informatics
J. Selye University
945 01 Komárno, Slovakia
E-mail: paksid@ujs.sk

✉ **Dr. Márk Csóka, Assist. Prof.**

ORCID iD: 0000-0001-9286-2780
Department of Informatics
J. Selye University
945 01 Komárno, Slovakia
E-mail: csokam@ujs.sk

✉ **Dr. Szilárd Svitek, Assist. Prof.**

ORCID iD: 0000-0002-8293-4899
Department of Mathematics
J. Selye University
945 01 Komárno, Slovakia
E-mail: sviteks@ujs.sk