E-COACHING METHODOLOGY

IN TEACHING LINEAR ALGEBRA AND CALCULUS

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"E-coach: Towards e-coaching – the first step to build trust with a digital coach" is an Erasmus+ project developed in international partnership between Bialystok University of Technology in Poland, Leipzig University in Germany, The Technical University of Crete in Greece and Tampere University of Applied Sciences in Finland. The goal of the project has been to develop a methodology for online coaching pedagogy in a university setting and a handbook and course material for both university teachers and students to help them move towards e-coaching. In this paper we present descriptions of our pilot distance classes with students, focused on selected material from linear algebra and calculus. We discuss methods, tools and summarise impressions from students and teachers.

Keywords: E-coaching, pedagogy, e-learning, linear algebra, calculus

COACHING IN EDUCATION

There are many different definitions of coaching, but one that has influenced our opinion of online coaching is Flaherty's definition [1], which focuses on the following effects of coaching: 1) long-term good results - coaching does not focus on short-term results. 2) self-correcting of their performance (by students) as individuals and as a team independently of the trainer, and 3) self-generating (learning) through practice in a way that continuously improves performance. In coaching, it is necessary to go beyond the idea that students are somewhat passive recipients of teachers' didactic interventions. The trainer creates the necessary atmosphere of mutual understanding and trust, openness to new ideas, indicates alternative ways, encourages students to create and implements independent decisions, ideas and projects. Coaching as a learning style can be used in any form of the educational process: during seminars, colloquiums, research, classes. Today, it is one of the most important directions, next to the use of new information and communication technologies in education [2][3]. The term coaching is increasingly used in the context of teaching at universities, eg. as guidance integrated with teaching. As a result of the change in teaching culture that the Bologna reforms required, from instructing to guiding student learning.

THE IDEA OF E-COACHING

Based on the extensive coaching literature available and the wide range of experiences available within the project team, we have selected four main themes that function as cornerstones of our e-coaching methodology: 1) trust, 2) dialogue, 3) ownership/responsibility, and 4) co-creation.

The cornerstones indicated in Fig. 1 form a whole system, because they support each other, and the coaching approach is built on them. Without any of these cornerstones, the online coaching

framework remains only partial. Teachers and students often find it easier to use the traditional delivery method. Especially if they feel pressure to minimize the extra workload.

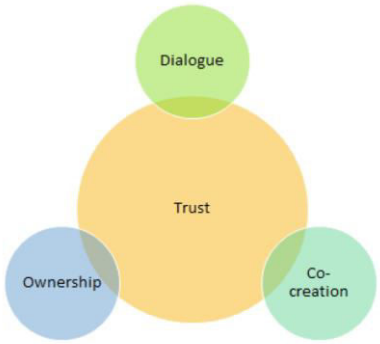

Figure 1. The four corner stones of e-coaching.

The basic building block of coaching is trust, both in face-to-face and online learning situations. In general, students and teachers can rely on two types of trust: trust that others will act the way they said they would and, more importantly, trust based on vulnerability [4, 5].

Dialogue can be defined as a collaborative exploration of experience and thinking, see [6]. In a given team, this is needed to understand the common situation and how it is perceived and understood differently by each team member. Dialogue is also great for building trust and even friendship between people with different cultural and social connections and personalities.

Ownership creates engagement and motivation. Ownership here means that students are the primary owners of their personal and team learning processes and the work they do together. This means a sense of responsibility for the results, but also an awareness of the impact that one's own actions and behaviour - including interactions with other people involved - have on the joint work. Facilitating a sense of ownership increases students' sense of autonomy, competence, and teamwork, which helps build and maintain their intrinsic motivation, [7], and initiative.

Co-creation in e-coaching means that the team engages in a creative process where they create something of value together. It can be a product, a service, a prototype, a solution to a complex problem, or an experiment they are involved in together. Co-creation is a collaborative mode of working that provides a context for coaching. Co-creation creates opportunities for all the other cornerstones of e-coaching: there is a clear need to build and maintain trust between the people involved, there is a clear need for dialogue to make sense of what is co-created and how, and building something together is one of the best ways to build a sense of ownership over the process and its end products, but also over the entire team.

STUDENT STATEMENTS DESCRIBING THE INDIVIDUAL CORNERSTONES OF E-COACHING

The following statements may initially be used by the teacher as a heuristic to think about the student's experience ("How would students respond in my course?"). Each cornerstone is associated with 3-4 statements that affect the cornerstone positively and one that affects it negatively.

Trust

(+) I feel that I can safely share my thoughts, experiences, feelings and even insecurities with the group.

(+) I can talk about the mistakes I've made or my insecurities without fear of being punished or ridiculed.

(+) The teacher, by example, encourages you to build trust by sharing your own mistakes, doubts or uncertainties from the past.

(+) The teacher shows a high level of confidence in our ability to learn and succeed in our joint efforts.

(-) I wouldn't feel comfortable sharing my weaknesses or weaknesses in the group.

Dialogue

(+) I feel safe sharing and talking about my own experiences and thoughts. I feel that others listen to me and respect me.

(+) Together, we explored, in a spirit of open dialogue, the different ways in which we think about the most important issues and problems.

(+) I actively take responsibility for the quality of my interactions with others to support the collaborative learning process.

(-) I feel that the teacher is not interested in how we think about the matter.

A sense of ownership

(+) I feel responsible for the topic and learning targets. The topic of the classes is related to my life goals.

(+) We have jointly established learning targets and quality criteria for performance.

(+) We can plan and implement our own ways of learning in a way that best supports our learning.

(+) We can set the pace of our work together keeping in mind the overall learning objectives and expected results.

(-) The teacher retains unilateral control over the work we have to do.

Co-creation

(+) Together we create solutions to complex problems.

(+) There is a place to practice creativity and innovation together.

(+) No one is left alone against their desires to deal with difficult problems or work that needs to be done.

(+) Everyone's intelligence and effort are appreciated and used.

(-) The course and success in it are mainly based on individual effort.

EXAMPLES FROM PILOT CLASSES

The three online linear algebra pilot meetings focused on the following topics:

1. Introduction to complex numbers.
2. Systems of linear equations and their applications.
3. Application of linear equations and inequalities.

In the math analysis class, we tested the new methodology in meetings about:

1. Applications of derivatives of functions of one variable.

2. Applications of definite integrals.
3. Selected applications of first order ordinary differential equations.

We cooperated with students of the Bialystok University of Technology from the following faculties: applied mathematics, computer science, computer science and econometrics, electronics and telecommunications. The students were in their first semester of studies. At each meeting, the group of students consisted of about 12-20 people. Then we divided the group into smaller subgroups of about 3-5 people. Three teachers attended the meetings. Each of us looked after one or two small groups of students. We used the following tools:

- MS Teams or any other application where you can create rooms for small groups.
- Online boards (MS Whiteboard) both in the main meeting and in virtual rooms.
- Other tools used by participants (unlimited).
- Cameras (if possible).
- Mentimeter or any other app for quick survey creation (modern, mobile, dynamic response).
- Additional materials, in particular in advance, were also posted on MS Teams.
- The description of the scope of the tasks performed can be found in the relevant courses on the Coursevo platform https://ecoach.coursevo.com/, developed by the Technical University of Crete, Greece.

HOW DID WE BUILD TRUST?

For example, by using the Mentimeter on menti.com to jointly build a word cloud as answers to the following questions (examples, results presented on Fig. 2):

- What's your superpower?
- What do you think about e-coaching?
- When are you most stressed?
- Who is your biggest inspiration in life?
- Other.

E-coaching methods used at meetings (dialogue, co-creation)

- Buzz Groups, i.e. discussion in small groups
- assigning a task/topic for discussion (for a limited time);
- providing a place to take notes (e.g. MS Whiteboard, OneNote, Etherpad, etc.);
- appointing a person in the group responsible for reporting;
- view the shared document and summarize the discussion;
- setting a short time frame for any questions.

Figure 2. An example of words cloud to build trust (from menti.com).

Selected methods of e-coaching

- The muddiest point of trust and co-creation;
- What? So what? What now? about ownership, dialogue;
- Peer instructions for ownership, co-creation, dialogue, trust.

Most of the methods were included in a teacher training course and a separate course for students on e-coaching methodology on the e-coaching Coursevo platform.

EXAMPLES OF PROBLEMS SOLVED DURING OUR CLASSES

Algebra 1. Introduction to complex numbers.

It was a kind of discovery lesson. Working in groups students tried to solve a quadratic equation with negative discriminant. Then they discuss the issue of algebra in a set of complex numbers. They define how two complex numbers can be added, multiplied and divide. We summarize each session inside small groups on a general channel. Then they were asked what set it is created when a complex number z=x+iy is multiplied by its conjugation is equal 1. It was the first step to find the definition of trigonometric form of complex numbers.

Algebra 2. Systems of linear equations and their applications.

The aim of the course was to apply systems of linear equations by students to solve specific practical tasks.

Students decided on the existence of solutions to posed problems related to the application of systems of linear equations. In small groups students started from the following Exercise 1.

Exercise 1. During the exam in linear algebra, students solved four five-problem sets A, B, C and D. The number of problems from five algebra divisions (complex numbers, polynomials, matrices, determinants, systems of equations) in individual sets was: 2, 1, 1, 0 , 1 in set A, 1, 0, 1, 1, 2 in set B, 0, 1, 2, 1, 1 in set C, 1, 1, 0, 1, 2 in set D. 50 students took the exam. The examiner checked, respectively, 47, 51, and 77 tasks from sections one, three, and five. How many sets of each group were in the room?

Algebra 3. Application of linear equations and inequalities.

The aim of the course was to describe the given optimization problem using linear equations and inequalities. In the considered decision problem there will be two variables, so one of the possibilities of solving the linear programming problem will be the graphical method. Before the classes, students were asked to familiarize themselves with the advance material available on the Khan Acedemy website:

https://pl.khanacademy.org/math/algebra/x2f8bb11595b61c86:inequalities-systems-graphs/x2f8bb11595b61c86:modeling-with-linear-inequalities/v/constructing-two-variable-linear-inequality-word-problem.

We propose to solve in small groups/rooms in MS Teams the following Exercise 2. Students discussed it at white board, shared ideas, built the model and then present in general room before other groups.

Exercise 2. The company produces two types of glass candles Z1 and Z2. Two limited raw materials are used during production: wax and glass - during the day a maximum of 240 kg of wax and 180 kg of glass can be processed into a finished product. At the same time, it is known that the production of Z2 candles cannot be greater than that of Z1 candles, and that the total production of both candles cannot be lower than 20 pieces. The inputs of raw materials needed to produce a unit of products are presented in the table:

	Candle Z1	Candle Z2
wax	6kg/pc	4kg/pc
glass	3kg/pc	6kg/pc
price	PLN 3	PLN 4

Determine the optimal daily candle production volumes that give the highest possible sales revenue given the given constraints. To do this, build a mathematical model (a set of constraints and an objective function). Enter the value of the solution. What is the maximum achievable income?

Calculus 1. Applications of derivatives of functions of one variable.

Before the classes, students were asked to familiarize themselves with the advance material provided in the form of videos available on the website:

https://pl.khanacademy.org/math/ap-calculus-ab/ab-diff-analytical-applications-new

The first question we posted for students to be solved in buzz groups was the following.

Exercise 3. What rectangle made of a piece of wire of length d has the greatest area?

The next one was

Exercise 4. Find the dimensions of a closed cylindrical tank with a given volume V and the smallest total area.

Calculus 2. Applications of definite integrals.

Integration of functions, like differentiation, is one of the basic tools used in the natural sciences. To some extent, we can think of integration as the inverse operation of differentiation. Definite integrals are used both geometrically to calculate areas of plane figures, arc lengths of curves, or

volumes of solids of revolution, as well as physical and mechanical ones. During the classes, participants will receive selected problems, the solution of which will require the use of a definite integral. After reading the material preparing for the classes in the form of videos available on the website: https://pl.khanacademy.org/math/integral-calculus/ic-int-app and materials presented in class, students will support each other in groups and solve given geometric problems.

Then we use an anonymous quiz with Mentimeter to check prereading material and after that we cam with groups to work over the following problems. The second, Exercise 6 was partially left as the homework.

Exercise 5. Calculate the area of the area bounded by parabolas

$$y = 4 - x^2 \text{ i } y = x^2 - 2x.$$

Exercise 6. Suppose we have a choice of two coffee mugs (see the picture below): the first (A) is bent outwards and the second (B) is bent inwards. Note that they are the same height and their shapes fit together perfectly. Let's see which of the cups holds more coffee? Of course, we can test this experimentally by filling one cup with water and then pouring it into another. However, we will choose a more mathematical approach to this problem. Ignoring the handles, we notice that both cups are surfaces of revolution, so we can think of the amount of coffee as the volume of a solid of revolution.

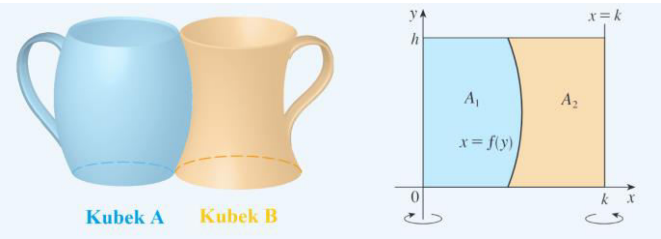

Figure 3. The illustration to Exercise 6. Source: I. Stewart, "Calculus".

(a) Find the value of k such that both cups hold the same amount of coffee.

(b) Can you give the areas of areas A1 and A2 shown in the figure above?

(c) How much coffee does each cup hold?

Calculus 3. Selected applications of first order ordinary differential equations.

Differential equations are used to consider many problems and have many practical applications. Most mathematical models are described thanks to them.

During the classes, participants will receive selected problems that are related to first-order differential equations. After reading the material preparing for the classes in the form of videos available on the website: https://pl.khanacademy.org/math/differential-equations/first-order-differential-equations and materials presented in class, students supporting each other will solve problems in groups (adapted to the field of study of selected students), which can be described by ordinary differential equations of the first order. As problems we typical description of RLC or RC circuits.

HOW DID WE SUMMARIZE THE CLASSES?

At the end of each meeting, we talked with students about their impressions, both directly on the general channel and also anonymously through the use of menti.com and mobile devices. See Figure 3 for an example of an automatic class summary.

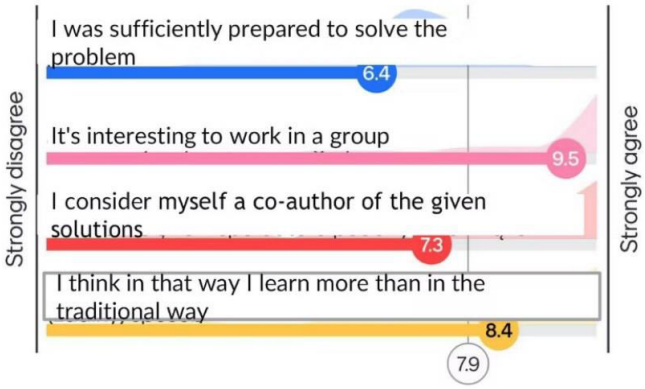

Figure 3. Summary of impressions using sliders on menti.com.

SUMMARY

The pilot classes conducted using the e-coaching method concerned selected topics from the indicated subjects. In addition, the students involved were volunteers who agreed to participate in online meetings and to record individual sessions. Recordings from the pilot meetings described in this article, together with the English translation, will be available on YouTube of the Bialystok University of Technology. Links can be found on the project website: https://ecoach-project.eu.

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REFERENCES

[1] Flaherty, J. (2010). *Coaching evoking excellence in others (3rd ed.)*. Elsevier.

[2] Fullan, M., Knight, J. (2011). Coaches as system leaders. *Educational Leadership*, 69, 50-53.

[3] Sushchenko, O., Mykhailivna, T. I., Ivanivna, B. D., Pokolodna, M. (2019). Coaching as Education Technology on Electrical Engineering Education. *2019 IEEE International Conference on Modern Electrical and Energy Systems (MEES).* Kremenchuk, Ukraine. 426-429. doi: 10.1109/MEES.2019.8896507.

[4] Lencioni, P. M. (2011). *The Five Dysfunctions of a Team: A Leadership Fable*. Jossey-Bass.

[5] Edmondson, A. C. (2019). *The fearless organization: Creating psychological safety in the workplace for learning, innovation, and growth*. Wiley.

[6] Isaacs, W. (1999). *Dialogue: The Art Of Thinking Together*. Currency.

[7] Ryan, R. M., Deci, E. L. (2020). Intrinsic and extrinsic motivation from a selfdetermination theory perspective: Definitions, theory, practices, and future directions. Contemporary Educational Psychology, 61, 101860.