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MONODISCIPLINARITY IN SCIENCE VERSUS TRANSDISCIPLINARITY IN STEM EDUCATION

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Abstract. *Contemporary society of the fourth industrial revolution (Industry 4.0) increasingly requires the education system (i.e., the school) to train competent, creative and proactive professionals who will be able to solve real life problems. If society is to achieve this, some key paradigm changes must occur in education. The school must first prepare a competence-based curriculum and, secondly, school practice should move away from subject-based teaching, towards an interdisciplinary STEM teaching approach. Obviously, to support this, modern learning environments and ICT solutions and tools have to be used. However, since the interdisciplinary STEM approach has already been implemented and integrated, it can be said that a new, integrated science discipline (STEM) has already emerged, together with a transdisciplinary approach to STEM learning and teaching.*
In the present research, a concrete case of designing, developing and producing a solar chimney was used to demonstrate an integrated approach to learning and teaching, while emphasizing especially the advantages of such an interdisciplinary (transdisciplinary) approach to teaching Science, Technology, Engineering and Mathematic content. The empirical research shows that such an approach produces incomparably better results, especially on higher cognitive levels, in comparison to traditional approaches to learning and teaching.
Keywords: *industry 4.0, interdisciplinarity, solar chimney, STEM, transdisciplinarity.*

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Introduction

In today's increasingly results-driven and performance-oriented world, the school system – with the necessary distance, of course, – is trying to (and should) follow such requirements. The question of an appropriate distance is very much relevant here, as "fast" changes are not always good or successful. In recent years (roughly in the period after the year 2000), especially under the influence of modern technologies and, in the last decade, under the influence of the Industry 4.0 guidelines, educational paradigms are changing dramatically, or at least, they should be. To name only a few of these changes:

- from traditional, teacher-centred teaching, to innovative, student-centred forms of education,
- from the passive learner (or, at a philosophical (paradigmatic) level, the behaviourist learning theory), to the active learner (or, the constructivist and cognitive theory),
- from traditional learning methods, to brain-based learning (BBL), which is based on findings from contemporary cognitive and neuroscience,
- from technology-based learning environments that required the learners and teachers to adapt to technology, to learner- and teacher-centred environments (Žbona, 2016), where the technology adapts to the needs of learners and teachers, and, last but not least,
- from subject-based teaching, to increasingly interdisciplinary oriented forms of teaching, supported, among other, by contemporary learning strategies, such as problem-based, research-based, and project-based learning (Aberšek, 2018, Key Competences for Lifelong Learning, 2006, Mayer, 2010).

Innovative education places various contemporary and innovative forms of organizing and performing teaching at its centre, where an integrative principle and a systemic approach to the education process are constantly emphasized:

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- Pedagogy 1:1 (Aberšek et al., 2017) underlines the significance of individualization and differentiation of teaching based on competence frameworks,
- the 20 Keys philosophy in education, inspired by Kobayashi's theory of organizing industrial processes from the early 1970s (Kobayashi, 2003), highlights the importance of a continuous and even development of all areas of a system, from the simplest, such as maintaining order and cleanliness, to the most complex. He accentuates the idea that only an equal development of all areas of a system can lead to a successful, optimised and thereby maximum effective production, supported by the total productivity management (TPM) approach. A similar philosophy is being introduced to the education system via the 21 steps system (Aberšek, et al., 2017, Clark & Svanaes, 2012; Microsoft Partners in Learning, 2010).

In focusing specifically on an integrated approach to performing teaching, the basic level of the education process itself should integrate at least the learners, as subjects of education, teachers, as managers and operators of the teaching process, and learning environments, which consist of learning technologies and methods and strategies of learning and teaching.

This research focused only on the latter, i.e., learning environments, their impact on the process of learning and teaching, or, in other words, their impact on the basic research question of this research, which is *how can changes in learning environments lead to improved results in both teaching and learning, and exert a positive effect on the efficiency of the learning process as a whole?* In order to achieve this, the (existing) learning process needs to undergo significant changes, namely:

- overcoming the division into individual subject areas and moving beyond the boundaries of individual scientific disciplines, and
- introducing methods and strategies that place students in an active role, making them co-responsible for their success in acquiring knowledge and competences, and thereby increasing their level of interest and motivation. Such methods are more or less based on research-based learning (RBL) and problem-based learning (PBL) (Aberšek, 2018).

Therefore, in order to form a complex, competence-based view on knowledge, and in order to direct learners towards a comprehensive approach to solving real-life problems, all of the above mentioned methods and strategies are connected into an integrated, complex strategy called project-based learning (PrBL). It needs to be stressed that projects are a form of team work, a group effort that requires collaborative learning, which means that learners involved in the process also develop their social competence and cooperativeness both on the level of implementation and organization (distribution of roles in a project, communication between the participants, negotiations, etc.). If in the context of RBL or PBL problems may still be "artificially" created, and solutions to the problem are proposed within "laboratory and local" frameworks of a particular subject (of a single individual discipline), then it can be said that project-based learning (PrBL) no longer considers teaching and learning from the standpoint of an individual discipline (i.e., monodisciplinary), but rather, it approaches the given problem in an interdisciplinary manner. However, since STEM is a kind of interdisciplinary, interconnected discipline in itself, it seems more appropriate to apply the term transdisciplinary to refer to the birth of a new discipline, which forms its own working and research methods (Flogie & Aberšek, 2015). Thus, a transdisciplinary approach creates a new perspective on learning and teaching, giving it a concrete expression and relating it to real-life situations and problems, to the real-life social environment and the requirements of modern society (Industry 4.0), for which the school should educate, whether creator of the school policy agree with it or not.

Course Development

General Background

In the proposed study the traditional approach to teaching physics on the example of renewable energy sources and ways of exploiting solar energy was briefly summarized. Unfortunately, such an approach, which is still predominant, has produced poor results in terms of enabling creativity and integrating knowledge for solving real-

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life problems (Hussain, Azeem, & Shakoor, 2011, Deslauriers, Schelew, & Wieman, 2011). A project-based approach to teaching similar subject-matter was presented in more detail, with a focus on using modern teaching technologies and contemporary learning approaches. An analysis and comparison of the two approaches was performed.

Development – A Case Study

The subject *Applied Physics* consisted of 60 contact hours and 60 hours of individual student work. On the topic of *Solar Energy,* a course of 12 contact hours was organized. Short course description and/or study design is presented in Table 1.

Table 1. Description of study design and procedures of the teaching/learning process.

Study	Multidisciplinary STEM approach - project-based learning (Example 2)	Traditional approach (Example 1)
Duration	12 contact hours 12 hours of individual student work (according to curricula)	12 contact hours ? hours of individual student work
Methods	Problem-based learning Research-based learning Collaborative learning Team working	Traditional teaching/learning methods such as lecture, frontal teaching, homework, frontal instruction lesson, etc.

On a concrete example of designing and optimising a solar chimney, this research compared two learning and teaching strategies, pointing out their advantages and disadvantages:

- the traditional approach (Example 1), related to the individual discipline, i.e., the monodisciplinary approach, and
- the multidisciplinary (transdisciplinary – STEM) approach (Example 2), related to solving real-life problems and founded on the idea of project-based learning.

Example 1: Traditional education in Applied physics (monodisciplinary approach) – Theory about energy and solar power

Focusing initially on the lesson about energy: it is common knowledge that two basic types of energy sources exist in the world. There are conventional sources of energy, most of which are non-renewable, for example fossil fuel, and renewable sources of energy, such as water or wood. Among the renewable ones, solar energy is the most prospective. A wide range of existing power technologies can make use of the solar energy reaching earth. Ways of harnessing solar energy can be divided into two basic categories: direct (transformed for use elsewhere or utilized directly) and indirect (involving more than one transformation to reach a usable form).

The output power of the plant depends upon various parameters presented simply by the following equation:

$$P_{out} = Q_{solar} * \eta_{coll} * \eta_{tower} * \eta_{turbine} = Q_{solar} * \eta_{plant} \quad (1)$$

If the temperature rise in the collector is (Ti – To) then it can be easily expressed as:

$$\eta_{coll} * I * A_{coll} = \dot{m} * Cp * (Ti - To) \quad (2)$$

The input energy from the sun, Q_{solar}, can be expressed as:

$$Q_{solar} = I * A_{coll} = I * (\pi/4) * D^2 c \quad (3)$$

One of the possibilities to study the use of solar energy is through the sun tower (sun chimney), which converts the heat-flow produced by the collector into kinetic energy (convection current) and potential energy (pressure drop at the turbine). Thus, the density difference of the air caused by the temperature rise in the collector works as

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a driving force. The lighter column of air in the tower is connected with the surrounding atmosphere at the base (inside the collector) and at the top of the tower, and thus acquires lift. A pressure difference Δp_{tot} is produced between tower base (collector outlet) and the ambient (White, 1999):

$$\Delta p_{tot} = g * \int_0^H (\rho 0 - \rho i)\, dH \tag{4}$$

This is simplified to:

$$\Delta p_{tot} = g(\rho_0 - \rho_i)\, H_t \tag{5}$$

The static pressure difference drops at the turbine, the dynamic component describes the kinetic energy of the airflow. With the total pressure difference and the volume flow of the air at Δp s = 0 the power P_{out} contained in the flow is now:

$$P_{out} = \Delta p_{tot} * v_t * A_{coll} \tag{6}$$

The mass flow rate is:

$$\dot{m} = \rho_i * A_t * v_t = \rho_i * (\pi/4) * D^2\ t * v_t \tag{7}$$

Thus, without the turbine installed, the total power available to the turbine can be obtained from equation (6). And also, the velocity at the entrance is found by,

$$v_t = \sqrt{2gH_t(T_i - T_o)/T_o} \tag{8}$$

Nomenclature:

Simbol	Meaning and units
Q_{solar}	Solar power input to the plant (W)
H_{coll}	Collector efficiency
H_{tower}	Tower efficiency
$\eta_{turbine}$	Turbine efficiency
η_{plant}	Plant efficiency
I_{Solar}	Intensity (earth surface) (W/m^2)
Δ_{ptot}	Total pressure difference (N/m^2)
g	Gravitational acceleration (9.8 m/s$^{2)}$
T_o	Ambient/outside temperature (°C)
T_i	Temperature at tower entrance (°C)
ρ_0	Outside air density (kg/m^3)
ρ_i	Air density at tower entrance (kg/m^3)
H_t	Height of the tower (m)
v_t	Air velocity at tower entrance (m/s)
D_c	Diameter of the collector (m)
A_{coll}	Area of the collector (m^2)
D_t	Diameter of the chimney (m)
A_t	Area of the chimney (m^2)

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It is only after the students have mastered the theoretical basics of physics, that they can move on to calculations and optimization of the solar chimney, i.e., to suitable experiments, to the technology and engineering part. This process, however, is time-consuming and requires a high degree of abstract thought and good spatial awareness skills.

Example 2: Project-based learning about energy (STEM approach)

The lesson could start by asking questions such as:

- How have people harnessed solar power through history?
- What must we know about using solar power?
- What kinds of elements does a solar power plant contain?
- Etc.,

and finally:

- How can we use solar power today? → Answer could be: By *Solar chimney*

Research start: A *solar chimney* – often referred to as a *thermal chimney* – is a way of improving the natural ventilation of buildings by using convection of air heated by passive solar energy. A solar chimney operates on the same principles as a fireplace chimney in houses. A simple description of a solar chimney is that of a vertical shaft utilizing solar energy to enhance the natural stack ventilation through a building. But is there another way in which the solar chimney can be used? *It can also be used as a power plant to produce electricity!*

What is needed to construct a solar chimney? How to build such a solar power plant? *With these questions, the lesson could start, students continue their research and try to come up with an optimal solution.*

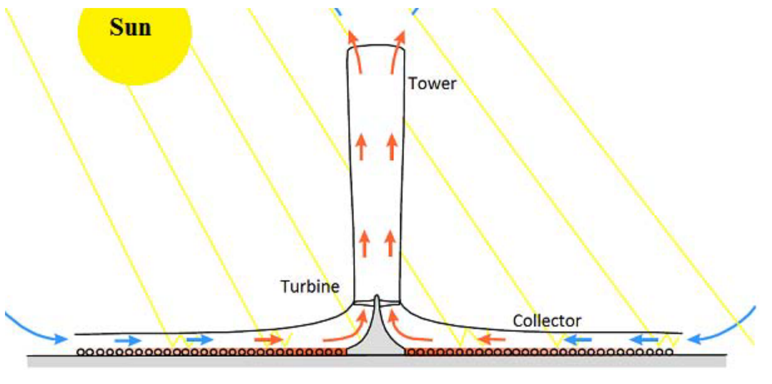

Figure 1. Simple diagram showing the functional principle of solar chimney plants.

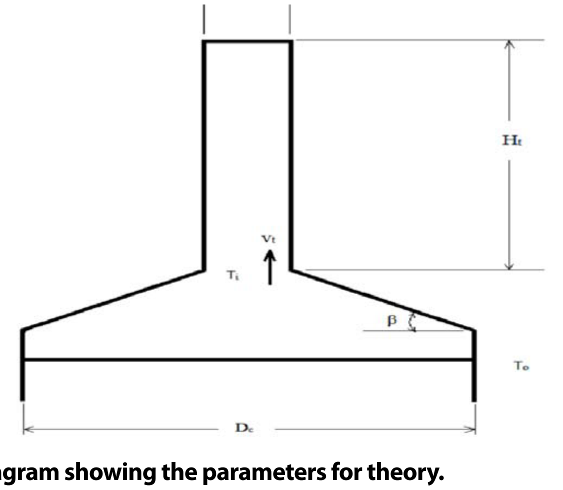

Figure 2. Simple diagram showing the parameters for theory.

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Research: What do we have to know? → The theory is learnt subsequently!

In the following stage, students begin designing the construction with the help of CAD programs. Possible solutions are shown in Figures 3 and 4. Students build the construction and then start experimenting using different engineering tools (for example ANSYS) for simulation – changing temperature, pressure, etc. and observing what happens to the speed and pressure of the air flow (for examples, see Figures 6–11), as they attempt to find an optimal solution. Simple physical models can be built by the students, or they can use numerical tools for calculating physical values. A draft description of the simulation (experimental) procedure is provided below:

1) the outside temperature T_0 was the input data, it was measured by thermometer;
2) temperature T_i was simulated by a computer program (it could also have been measured at the same time (as the outside temperature) by thermometer);
3) the air velocity at the entrance of the tower v_t was calculated/simulated, as shown in Figure 7 (it could also have been taken by using the anemometer);
4) the densities ρ_i and ρ_o were simulated automatically by means of numerical simulation (they could also have been taken corresponding to the temperatures T_i and T_0 respectively);
d) steps 1 to 4 were repeated in any new simulation (this could have been done experimentally, by repeating them once every half an hour for the time period of one day);
e) in this way, data was collected for six (6) simulations (experimental days) and in turn, the necessary calculations were made.

Simulation as a Learning Strategy

Presented experimental procedure can be simulated (Žbona, 2016) by means of Finite Element Analysis (FEA), the Finite Element Method (FEM), with various computer programs (such as ANSYS), in order to provide an optimal solution easily and quickly.

Using one of the various engineering tools for modelling 3D constructions (Computer-Aided Design – CAD), it is possible to model any desired form of construction, in the case of this research, a solar chimney. The advantage of using CAD tools is in that they allow flexibility and rapid changes in the design, depending on the simulations performed and the calculations obtained. An example of an initial construction of a solar chimney is shown in Figure 3.

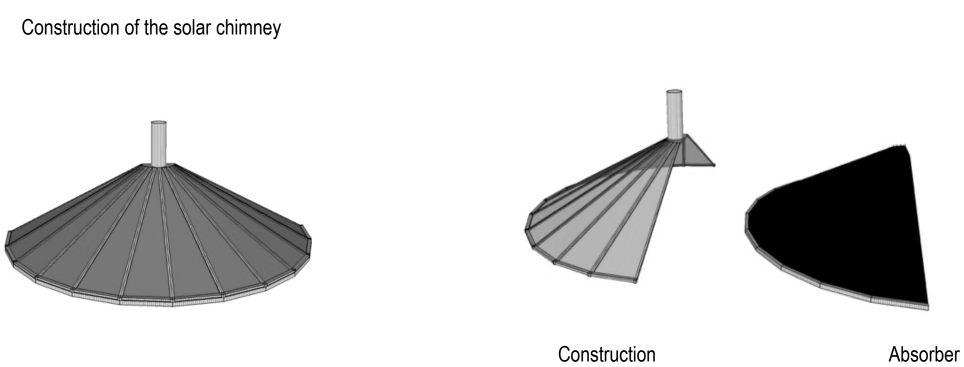

Figure 3. Simulation with using C AD possibilities (using SolidWorks).

Once the basic construction has been modelled with CAD tool, we can use this model as input model in FEA, where first, surfaces need to be specified (Figure 4), to which boundary conditions will apply, before further simulation using the Finite Element Method (FEM). For surface A (Figure 4), the pressure of 1 bar was prescribed, and for surface B the pressure prescribed was lower by $\Delta p = -\rho g \Delta h$ due to a height difference, which was 2,8 m between the two surfaces. Thus, the pressure difference was $\Delta p = -35$ Pa. No value was prescribed to other surfaces in this simulation.

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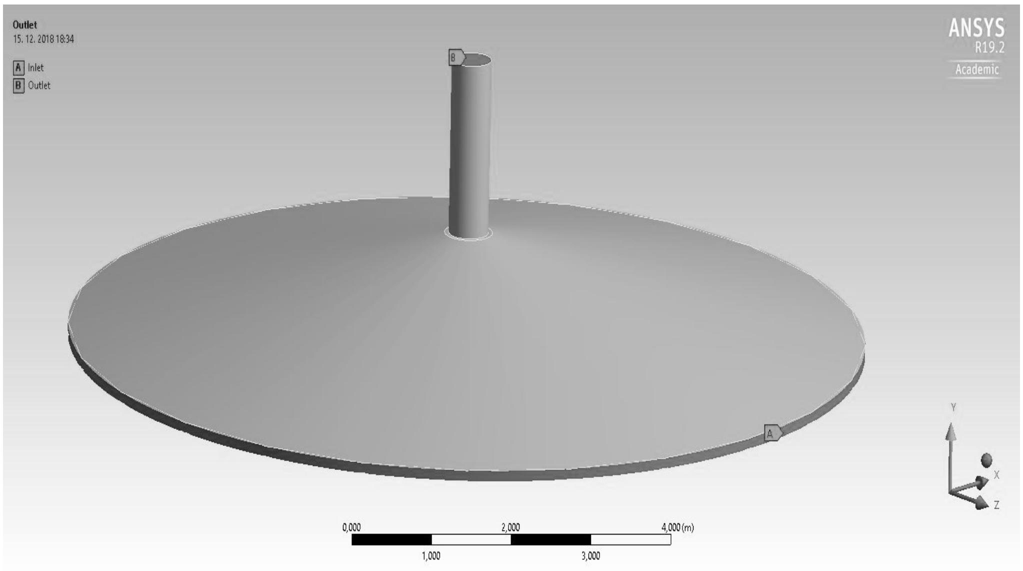

Figure 4. Defining boundary and initial conditions.

The next step is creating a volume mesh, see Figure 5. For the purposes of this research, a volume mesh was created consisting of poly cells. For the creation of a volume mesh, it is necessary to prescribe the size of cells, the same size across the entire mesh. The cell size in this research was defined so that approximately 5 to 10 cells fit the thickness of the structure (0.1 m).

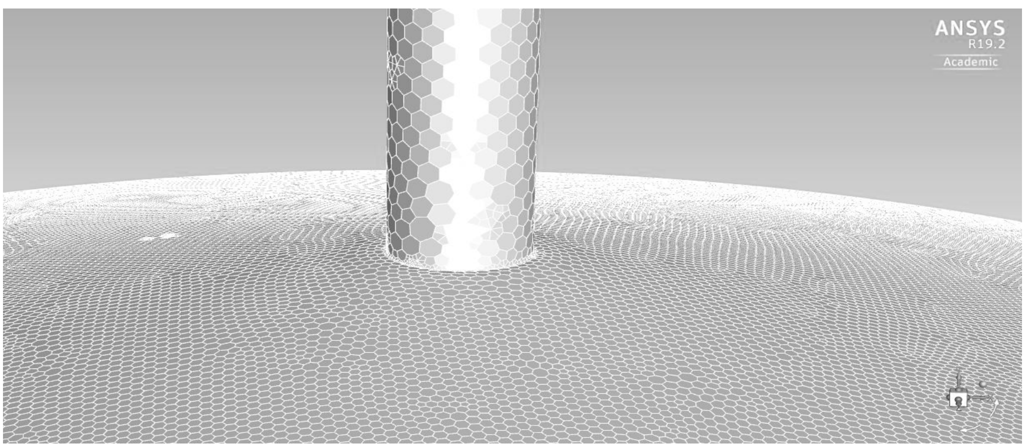

Figure 5. Volume mesh.

On the basis of such a volume mesh, various causal relationships can now be identified. Thus, the pressure field shown in Figure 6 shows the pressure in the selected cross-section of the computational network. Figure 6 shows areas of elevated pressure at the centre of the chimney, which occur due to the merging of flows in that area.

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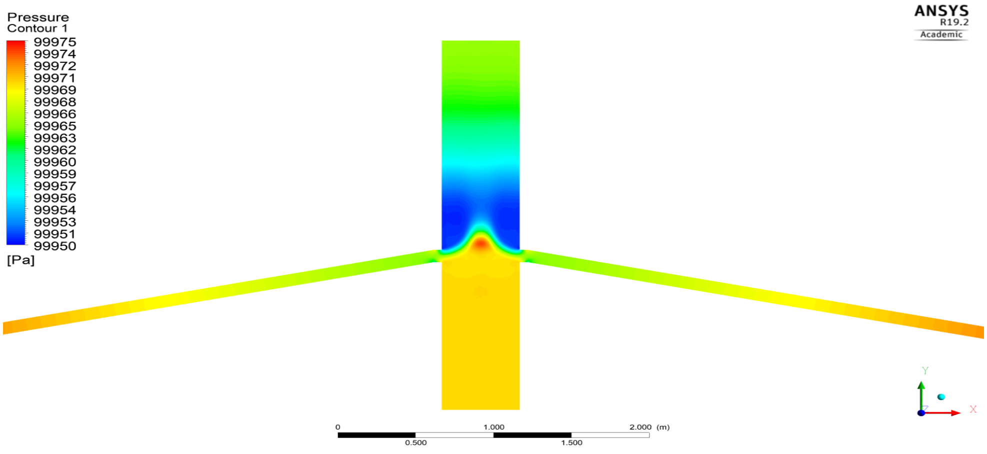

Figure 6. Pressure field in a solar chimney.

It is also possible to simulate what happens in terms of the velocity field, which shows the speed of the air flow. Thus, for example, Figure 6 shows that the maximum speed of the air flow is where the solar roof joins the main part of the chimney, which is also the optimal location for placing the turbine(s).

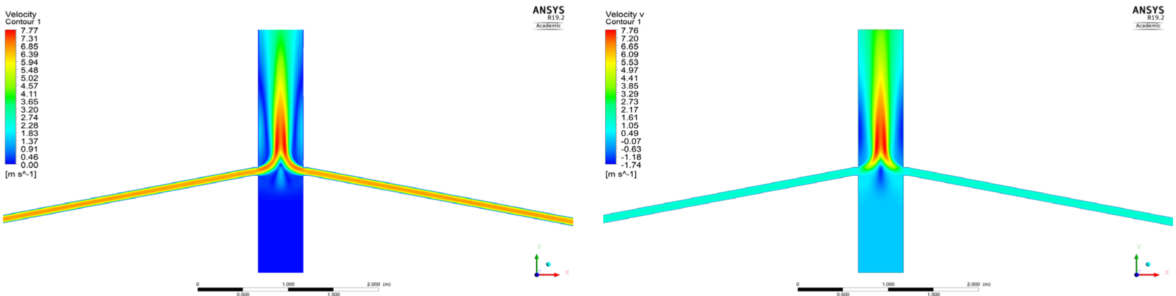

Figure 7. Velocity field of the air flow: a) inside a solar chimney and b) in direction y.

The velocity field in Figure 7 also shows that upon merging, part of the air flow is directed downward, which is undesired (see Figure 8).

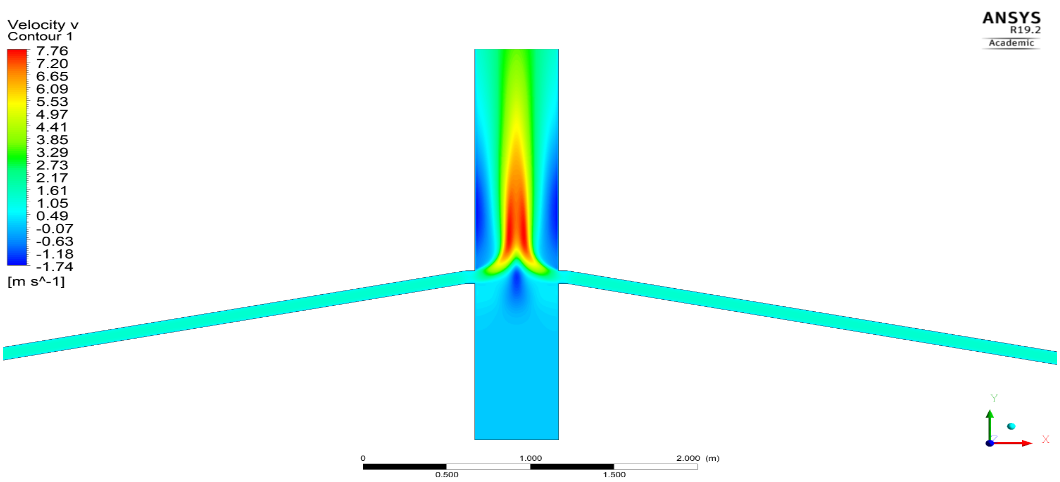

Figure 8. Air flow in the direction of the z axis.

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This undesired issue could be resolved by closing the bottom part of the chimney, while an even better solution would probably be to alter the way in which the entire construction is closed, which is shown in Figure 9 (see square on bottom).

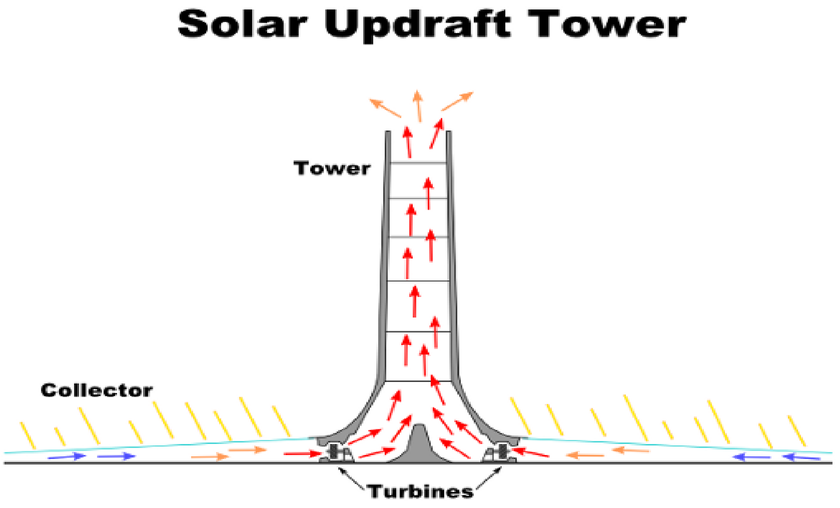

Figure 9. Theoretical (anticipated) air flow in a solar chimney.

Focusing more closely on the area where turbines could be placed for the production of electrical energy, the course of the air flow can be demonstrated in various ways, including streamlines, which are shown in Figure 10.

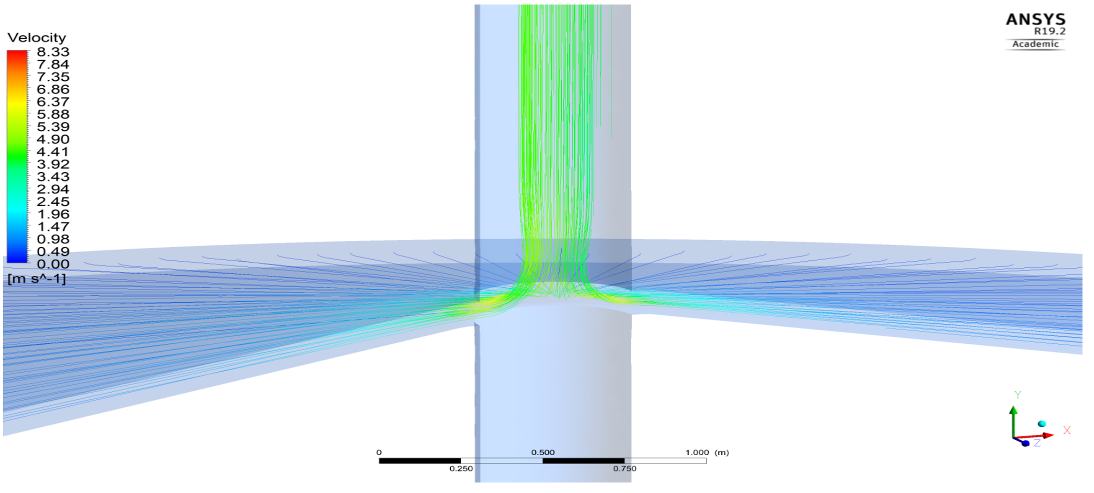

Figure 10. The field of air flow inside a solar chimney.

The streamlines show the turbulence of air inside the solar chimney. This is confirmed by the turbulence field, which is undesired in this case. Various simulations are used to determine what kind of form will result in a laminar field. Figure 11 shows where the turbulent flow is most likely to occur.

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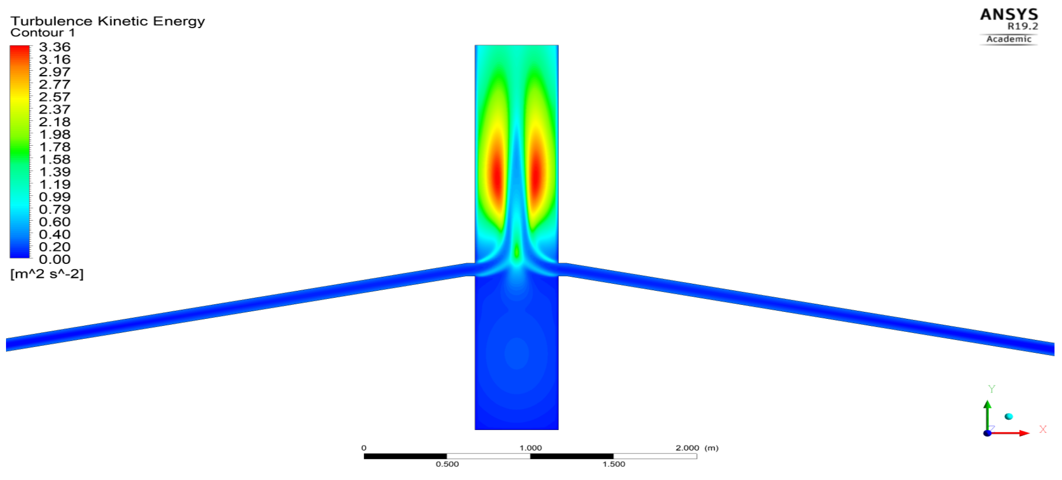

Figure 11. Turbulence field and turbulent flow occurrences.

From a comparison between the turbulence field in Figure 11 and the streamlines in Figure 10, it can be concluded that the turbulent flow occurs mainly in the areas with a higher level of turbulent energy. It can also be seen that the turbulent field is largely symmetrical (with regard to the symmetry of the chimney's main pipe), which is the expected result. On base of such analyses and simulation it is possible to find out optimal solution.

Sample

The research was conducted during the subject Applied Physics, which is taught at the Faculty of Natural Sciences and Mathematics of the University of Maribor in the fifth year of the study course. The research included 20 respondents: 9 male students and 11 female students. The sample size depended on the total number of students in this class, and represents nearly 80% of all students enrolled in this class.

Research Methodology

General Background

According to the chapter Course Development lecture was presented to the students by means of a traditional, frontal instruction lesson. This is referred to as Example 1 in the following section. The teacher provided an explanation of the topic and relevant formulations, while the students took notes and studied from them. During the next lecture, two days later, they filled out a test.

After the period of one month, the test was repeated with the same questions and based on this, the forgetting curve was calculated. The standardized Ebbinghaus forgetting curve is shown in Figure 12 (Ebbinghaus, 1908, Schacter, 2001).

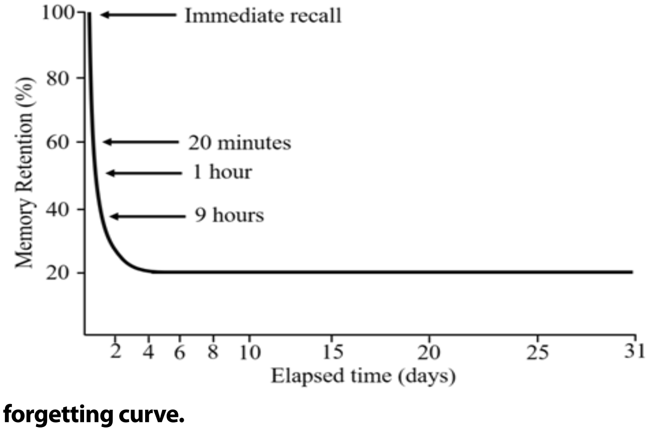

Figure 12. Ebbinghaus forgetting curve.

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After the test, the lesson was repeated as a problem-based learning according to the described STEM model (Example 2). Just like with Example 1, the students were asked the same questions two days after the initial lecture. The test was repeated again, just like with Example 1, in one month's time.

In both cases, the answers were assessed and evaluated individually and independently (by two professors, two assistants and two students) with grades from 1 to 10, depending on the correctness and completeness of the answers. The overall grade was calculated as an average of all individual evaluators' grades.

Instruments

The differences in the effects of teaching strategies between Example 1 and Example 2 were tested by means of a questionnaire in terms of the following indicators:

- *knowledge* of the subject matter dealt with,
- *understanding*, which is demonstrated by *relationships / attitudes* in the group, the students' personal *development,* and the *systemic* characteristics of individuals,
- the ability to analyse and synthesize (the ability to reach higher cognitive levels) and
- digital competence (digital skills of providing an analysis and evaluation using modern engineering tools).

The effect of the applied method of work after the end of the lectures was evaluated according to four individual phases of solving the problem (idea, design, production, evaluation), resulting in a common assessment. The evaluation was performed under conditions of statistical control using a *t*-test, a Cohen's *d* effect size calculation, and a graphic representation. Each of the dimensions contained a specific number of statistically and graphically validated propositions in the form of questions and task.

With the questionnaire the effect of the method of work after the lectures was measured. The questionnaire consisted of 12 descriptive questions:

- idea (3 questions),
- design (3 questions),
- modelling (3 questions),
- evaluation and optimisation (3 questions).

that were performed as part of lectures on the theme of *Design, construction and analysis of a solar chimney.* The effect of the method of work used by students was analysed after the lectures had ended:

- the students' interest in methods of learning and teaching, expressed as the overall result of all dimensions of interest, shown in Figure 13 and
- the students' interest in methods of learning and teaching, expressed as the individual result of each dimension of interest (idea, design, production, planning) separately, shown in Table 2.

Research Results

A graphic representation of distribution of arithmetic means is at Figure 13, and *t*-test, Cohen's *d* effect of the following dimensions of interest is presented in Table 2.

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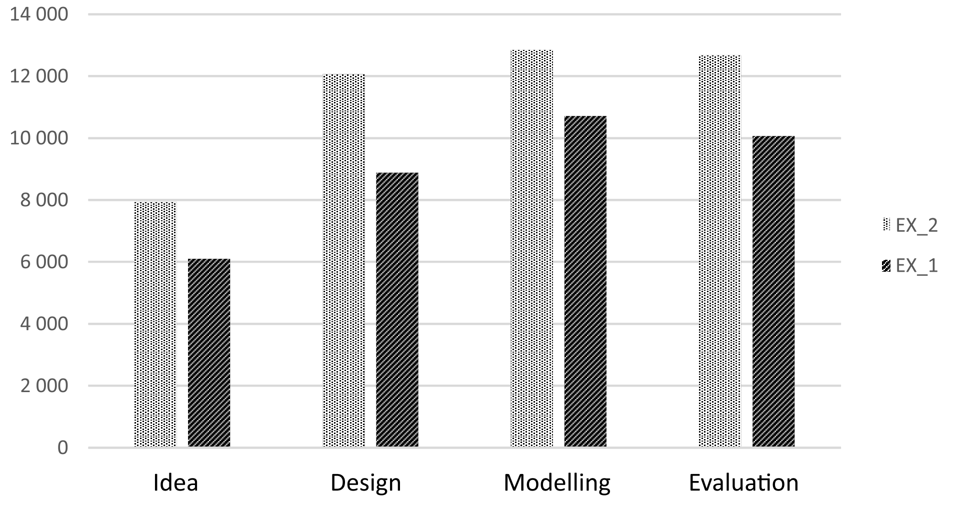

Figure 13. Arithmetic means of evaluations of students' interest according to the method of teaching (Example 1 (EX_1) or Example 2 (EX_2)) for individual dimensions.

Table 2. t-test results for independent samples of testing differences between the overall and individual results for representability according to the group EX_1 and EX_2 after the experiment.

Group		Arithmetic mean	Standard deviation	Test of variance homogeneity*		Arithmetic mean differences test		Cohen's
		$\bar{x}$	*SD*	*F*	*p*	*t*	*p*	*d*
Idea	EX_2	7.935	1.181	27.589	.0001	5.063 approximation	.0001	1.099
	EX_1	6.109	2.142					
Design	EX_2	12.065	1.665	16.342	.0001	6.809 approximation	.0001	1.460
	EX_1	8.870	2.713					
Production	EX_2	12.848	1.429	10.776	.001	5.548 approximation	.0001	1.178
	EX_1	10.717	2.177					
Evaluation	EX_2	12.674	1.431	12.679	.001	5.973 approximation	.0001	1.296
	EX_1	10.065	2.594					
Method effect	EX_2	45.522	3.863	21.743	.0001	7.456 approximation	.0001	1.646
	EX_1	35.761	7.995					

** In all cases, the assumption of homogeneity of variance is not justified ($p < .05$), hence results of the approximation method are reported.*

The degree of forgetting in both learning situations was measured as well, and the results were compared to known results from traditional teaching settings (Ebbenhard, 1908) and superlearning (Ostrander & Schroeder, 2012). The results are shown in the Figure 14.

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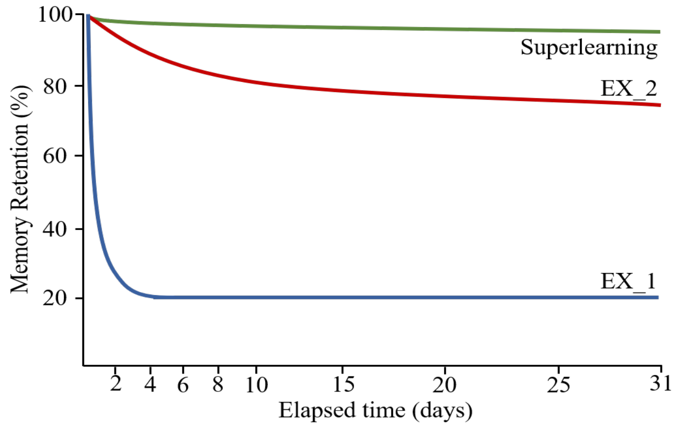

Figure 14. Diagram of the three forgetting curves.

For the presented case, an additional test was conducted only three months later. Example 1 produced similar results to those obtained by Ebbenhard in his research, while for Example 2, the results were slightly lower than in the case of superlearning.

Discussion

The graphic representation in Figure 13 shows that the line of Example 2 is above the line of Example 1 for all dimensions (idea, design, production, evaluation), whereby the differences are significant, which was confirmed by the results of statistical difference testing. The most marked differences between the two Examples are observed in the case of design (it is here that most innovative tools and approaches were used, from CAD to FEA), and the smallest differences in the dimension of ideas.

The *t*-test proved (Table 1) that the difference between Example 1 and Example 2 after the lectures ended is statistically significant ($p < .05$) for all dimensions of the effect, i.e., for the individual dimensions (idea, design, production, evaluation), as well as for the overall effect (interest):

- idea ($p = .0001$, $d = 1.099$),
- design ($p = .0001$, $d = 1.460$),
- production ($p = .0001$, $d = 1.178$),
- evaluation ($p = 0001$, $d = 1.296$),
- summary effect size of the method of teaching ($p = .0001$, $d = 1.646$).

As demonstrated by measuring the effect size of Cohen's *d* ($d > 0.80$), the effect size of the method is different for both examples. The greatest effect was observed in designing the product ($d = 1.460$), followed by evaluation ($d = 1.296$), production ($d = 1.178$), and searching for ideas ($d = 1.099$), where the effect size was the smallest. The obtained average values of the evaluations ($\bar{x}$) of interest in Table 1 show that the students evaluated all dimensions of efficiency higher for Example 2 in comparison to Example 1, which consequently affects also the overall efficiency of the method of teaching. With regard to Example 2, the students did better in coming up with ideas, designing the product (chimney), producing, and evaluating the product. This means that the students, as regards Example 2, made more progress in the phase of designing, than in the phase of evaluating the product. Indeed, more time was spent on designing the product, especially on CAD modelling and engineering calculations and analyses (FEA) with the help of the Finite Element Method (FEM), which was a novelty to the students.

Great efficiency was achieved also in the sense of memory retention: if traditional teaching led to a degree of forgetting almost as high as 75%, after one month then the proposed approach has reduced the level of forgetting to 25%, which is very close to the standard curve of superlearning (Ostrander & Schroeder, 2012). It needs to be taken into account, however, that these were not two different groups of students; the group in the case of Example 2 was left with only some (25% at best) of the previous knowledge, but the progress was nonetheless

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evident. What is especially important, higher and in-depth cognitive levels of knowledge were stimulated in the students, as well as critical thinking and competences for solving real-life problems, which is the essential purpose of both, problem-based approaches to teaching, as well as the proposed STEM model. Similar results were reported by various other authors, including (Hussain, Azeem, & Shakoor, 2011, Deslauriers, Schelew, & Wieman, 2011) and many others.

Conclusions

It should be emphasized that the findings derived from this research are preliminary, the research was carried out on a small sample (mostly due to a small number of students in the class) and the research would certainly need to be continued including a larger sample (also international), which would allow the formation of two separate groups, the experimental one, where the proposed STEM model would be applied, and the control group, where lectures would be delivered under the existing approach. It would also be reasonable to track the course of forgetting over a longer period of time, which is rather difficult within the academic environment, as lectures only last one semester. Therefore, it would be a good idea to organize the survey as a project in a way that would allow the monitoring of (larger groups of) students over a longer period of time.

The obtained results, however, clearly show that the proposed approach resulted in a number of positive shifts. To name only the most important ones:

- the students' interest was increased;
- the students' acquired knowledge and understanding were enhanced and finally
- the students' digital literacy was increased, and, it was proven that problems can be addressed and solved in different ways. At the same time, the students were encouraged to form a comprehensive approach to problem-solving.

Nevertheless, some possible disadvantages need to be mentioned as well. A one-dimensional use of contemporary engineering tools in STEM education could lead to a superficial understanding of the problem dealt with. This method requires not only focusing on the results, but especially on the procedure itself and the level of understanding, to avoid arriving to incorrect conclusions.

STEM learning and teaching is a reality that enables the acquisition of competences, which are important for successful problem-solving in the 21st century society. Of course, STEM teaching and learning requires a mind shift with regard to methods of imparting knowledge and conceptual changes in education from the primary to the tertiary level. The presented example represents a concept of teaching for the society of the fourth industrial revolution. The sooner the needs for conceptual changes in education are realized, the less painful these necessary adaptations are going to be.

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