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Becoming An Expert In Soft Robotics In One Week And Beyond!

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ABSTRACT

The Athens network of technological institutions and universities offers students international exchange experiences through intensive specialization courses during a brief period. Yet, it is challenging to effectively explain complex research topics to students in only one week, while offering at the same time self-paced learning perspectives instead of absorbing expert lectures as a passive student. Furthermore, students often experience a knowledge gap with the 'international experts' they are consulting, which hinders vivant exchange of ideas during discussions. In this context, we report our experiences of a newly designed crash course within the field of soft robotics that was offered to a group of international students. Our approach is a concept of combining flipped teaching, peer learning and student empowerment within engineering sciences. A scenario is elaborated and finetuned in which students experience a set of (semi-)self-paced activities and achieve the learning goals in a (semi-)independent way. This includes a preparatory activity and, on the spot, (re-)active learning through peer-discussion on emerging topics in the field of soft robotics and collaborative creation of a simple, functional, soft robot. The daily progress of the research topic and design challenge is checked, and the progression of the associated expertise is mapped. Students especially appreciate the positive atmosphere with a focus on a growth-mindset, the teamwork experience, and the opportunity to discuss on an expert level. The message we wish to pass is that our transferrable educational setup generates strong learning dynamics that radiates out to the students and the supporting didactic team.

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1 INTRODUCTION

The ATHENS program enables students to attend for one week a 3 ECTS course, offered by network universities, facilitating the exchanges of students coming from European technological institutions. As such, students experience being immersed in another educational system. The Faculty of Engineering Science of KU Leuven organizes several ATHENS courses each year and educational developers explore new opportunities to incorporate active learning formats, with a prime focus on blended learning. We refer to this as virtual mobility, in which the addition of blended pathways to a short-term physical mobility trajectory enables extra learning opportunities.

In this context we accepted the educational challenge to introduce engineering students into the field of soft robotics, which is a subfield of robotics that focuses on the design, control, and fabrication of robots composed of compliant materials, instead of rigid links (Rus and Tolley, 2015). It is challenging to design and implement a new course in such rapidly evolving fields of engineering sciences, especially if no overview textbooks are directly available and frontiers of current knowledge are fragmented across several European research groups, risking an overload of details and loss of knowledge links. By simply inviting senior scientists that overwhelm students with a series of standard, condensed lectures, the desired vivid exchange of ideas between students and invited lecturers is absent, which contrast our intention of integrating active learning formats as much as possible. Qualitative interviews of similar rigid setups indicate that students perceive an inequality of knowledge with respect to the experts, resulting in a discomfort to actively contribute during discussion moments and a fear of embarrassment when asking questions (e.g., Forbrig et al., 2022).

Forbrig et al. (2022) radically reorganized their course design by focusing on the creation of a student-oriented learning arrangement to gain the needed theoretical knowledge of a newly introduced study field within a limited period (a so-called one-week setup). A key aspect is keeping the commitment of invited experts to a minimum yet maximize their indirect contributions. Their concept is the basis of the practice experience elaborated here, with a higher focus on problem- and project-based learning (De Graaf and Kolmos, 2007). Based on these conditions, we designed an introductory course to bring students rapidly to a more advanced level of capturing the research and application frontiers in soft robotics, interconnected with the expertise present at KU Leuven and within Europe. As no comparable course format is available, we wish to share our insights of our newly designed setup. Here we report our design process, the experience and our intentions for further improvement.

2 OBJECTIVES AND METHODOLOGY

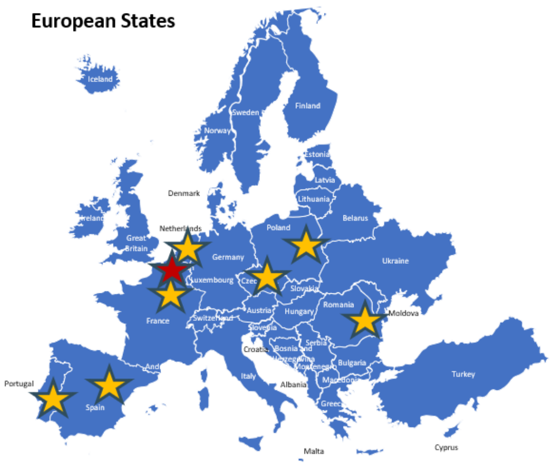
2.1 Intended learning goals

By introducing soft materials in the design, soft robots become safe in interaction with humans and other delicate objects. However, their analysis does not fit the traditional hard robotic framework. In this course, students receive a broad introduction to the field for soft robotics and three learning goals are put forward:

1. students acquire the necessary skills and knowledge to create self-made inflatable soft robots by problem definition and specification (goal 1);
2. students understand how to design, fabricate and control these new types of robots, plus applications in various scenarios (goal 2);
3. students are familiar with state-of-the-art research topics in the soft robotics domain and are open for in-depth discussion and create new insights (goal 3).

2.2 Student group and networks of European technological institutions

In the framework of the CLUSTER network (see https://cluster.org/), the Faculty of Engineering Science at KU Leuven intends to transform several spearhead courses to enable short-term mobility possibilities between CLUSTER partners. By adding an additional blended pathway to physical mobility, we anticipate increasing the learning opportunities for students who follow courses within this network, thus creating extra (virtual) layers in the available learning spaces (e.g., Ellis and Goodyear, 2016). However, there is still a need for an elaborated didactic framework, especially for activities that are commonly used within engineering sciences and including aspects of international and intercultural learning and collaboration. This elaborated case can provide input and inspiration for further expansion of the virtual mobility concept.
The ATHENS program is aimed at carrying out intensive specialization courses during defined short periods (see http://athensnetwork.eu/athens-programme.html), enabling students to attend courses offered by the network, and have a great potential to be incorporated in a virtual mobility context. These ATHENS weeks enable students from different institutions to take short courses of a high scientific level and to mix with students of different nationalities and backgrounds. This learning experience at other European institutes, in many cases, gives students the desire to conduct studies of a longer duration (MSc and PhD levels) at an institution different from their home institution. Each ATHENS week includes both 30 hours of scientific activities as well as 10-15 hours of 'European Dimension' social and cultural events, reflecting a 2 to 3 ECTS credit course and includes an examination organised by the host institution. In total, 22 students coming from 7 network technological universities, subscribed for the offered course in soft robotics (Figure 1). All these engineering students are either in the end phase of their bachelor program or are studying at a master level and consequently have limited or no prior knowledge on soft robotics.



- Polytechnic University of Madrid
- Polytehnica University of Bucharest
- Czech Technical University
- Arts et Métiers Paris Institute of Technology
- IST Téchnico University of Lisbon
- Delft University of Technology
- Warsaw University of Technology

Figure 1: Map with the organizing ATHENS university in red (KU Leuven course in soft robotics) and student's ATHENS home universities in yellow.

2.3 Educational approach

Attention is given to the qualifying (knowledge buildup), socializing (interpersonal collaboration within the discipline) and subjectivizing (development as a person) dimensions of learning, directly focusing on the adequate development of their disciplinary future self as an engineer. Emphasis is on the didactic aspects within an international and intercultural context, which will turn an ATHENS course into a student-focused format with higher higher-order thinking skills (Anderson and Krathwohl, 2001). Our focus is on inquiry (learning by finding out), collaboration through peer-discussion and collaborative creation (learning by doing). In our setup, students rapidly pass the stage of passive listening, which often merely focusses on aspects of remembering and understanding of theoretical facts and applications, and start an educational journey towards analyzing, evaluating, and creating by placing theoretical elements of soft robotics and methodologic approaches into a coherent story. Groupwork in a collaborative learning space is considered as one of the most effective learning environments for these purposes, considering our learning activity-centered analysis and design (Goodyear et al., 2021). As such, groupwork by discussion and co-creation is the dominant activity students executed in the collaborative rooms (Figure 2).

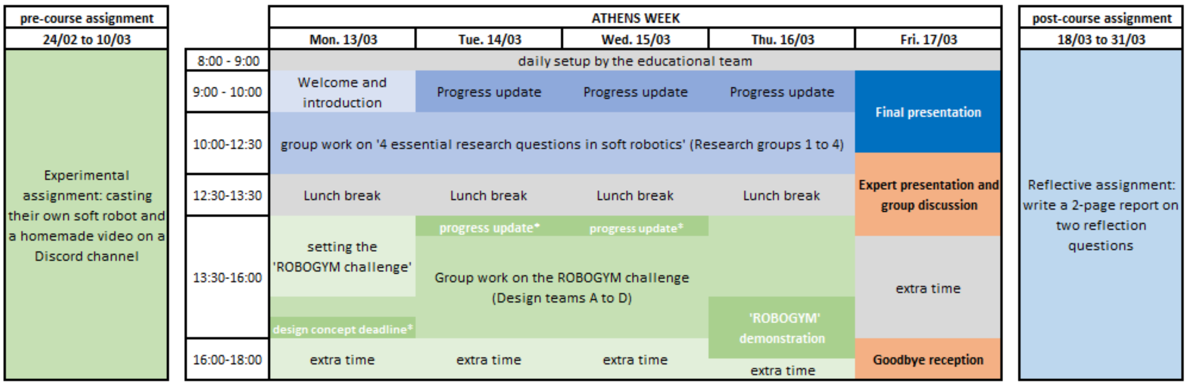


Figure 2: Planning of learning activities to become an expert in soft robotics in only one week (are potential educational improvements).*

2.4 Course development and learning objectives

During creative ABC sessions (Young and Perović, 2016) and ACAD design (Goodyear et al., 2021) learning objectives were listed and discussed with members of the educational team, including two educational developers and the direct involvement of PhD-students. The ABC framework assumes six active learning activities that describe how students interact with the material and construct their knowledge. Four of these (acquisition, inquiry, practice, production) refer to individual learning, while collaboration and discussion refer to social learning. From the start on, we had the intention to let students primarily build lasting knowledge in a self-paced context by cycles of learning activities, rather than absorbing traditional lectures as a passive student. At the same time, students foster sufficient expertise and self-confidence to engage in lively discussions with experts and thus become acquainted with a vast and growing field of research. As the course has time constraints - the on-campus activities must be organized within a timeframe of 5 days (Figure 2) - four main learning objectives emerged, namely:

A. creation of experimental silicon rubber actuators using simple molds and understanding the fundamentals and pitfalls of this technique;
B. design, create, evaluate and demonstrate a soft robot that can pass several obstacles (including problem definition and specification);
C. master a specific research topic by literature study and peer discussions;
D. a personal (written) reflection on state-of-the-art research and evolution of the scientific field through self-reflection.

3 COURSE OUTLINE

3.1 Pre-course assignment

Approximately two weeks before the start of the ATHENS week (figure 2), students receive a 'Do It Yourself' soft robotics kit, giving them basic materials to create self-made inflatable soft actuators (leaning goal 1 and learning objective A). This DIY kit contains 2-component silicone rubber, a syringe, connection pieces, safety gloves and an instruction flyer. Via this first experimental assignment, the students cast their own soft robot at home and experience first-hand the capabilities and limitations of soft actuation and production. The amount of silicone rubber is intentionally limited to ensure students focused on a well-thought approach instead of playing around. The first assignment for the students is three-fold and students follow the procedure to:

- fabricate a first soft structure by shaping rubber in a generic mold;
- create a soft inflatable actuator that displays an extension deformation when inflated and measure the deformation of the actuator during inflation.
- based on the lessons-learned from their own experiments and from the experience of others, we ask to students to reflect and retry.

Students are thus instructed to pay extra attention to their design flaws they discover or experience, plus post their results on a forum for discussion and reflection with their peers. The students thus initially work independently and capture their achievements on a homemade video, which is subsequently shared with fellow students via a dedicated Discord channel. The use of such a digital platform promotes high-quality active participation and design strategies, which theoretically lead to significant better end grades (e.g., Miller et al., 2018). Students also get to know each other in advance in an interactive way.

3.2 ATHENS week – Research groups and design teams

During the ATHENS week, research groups are formed (groups 1 to 4 in figure 3) and each group has a different research topic to master (supplement 1). Based on a selection of additional trigger questions and tag words, students conduct background research and give a daily update for their peers, plus a final presentation on day 5 for invited soft robotics experts, thereby getting fully prepared for an in-depth discussion with experts and peers. This aligns learning goal 2 with objective C, as students learn to understand the essential problem definitions and solutions offered in the literature that are all connected to the design, fabrication, control and application of soft robots. Students thus elaborate an essential research question over 5 days, supported by additional sub-questions each day and the gradual release of accompanying literature (articles, conference papers, video's, etc.). Students are also required to present their intermediate progress each morning, receiving direct feedback from the mentors (teaching assistants and professor) on how to proceed further while fine-tuning their research question. On day 5, experts join the final presentation and afterwards, show their state-of-the-art research. During these expert presentations, in-depth discussion is stimulated, merging multiple research questions into one comprehensive overview of the main research topics (learning goal 3 and learning objective D).
During the afternoon sessions, learning activities are focused on the actual creation of self-made, functional, inflatable soft robots (learning goal 2 and learning objective B). These design teams (teams 1 to 4 in figure 3) focus on experimental aspects and develop rudimentary soft robots by using everyday components (balloons, tubes, straws, syringes, etc.). During these self-paced design sessions, informal feedback is

given by the mentors if students face design problems. The students need to go in competition with each other and develop an inflatable soft robot that navigates through an obstacle course. However, the main learning activity is to be creative and experiment with the fabrication, actuation, control and navigation (skill development of learning goal 1). Students thus need to assess and define the ‘obstacle’ problem by adding design specifications or additions to their soft robot. Four adjustable obstacles are given, all connected to different motions and each group can adapt the severeness of the obstacles, to gain more points (see supplement figure 2). As such, success can be expressed by their capability to pass the obstacles. This Robogym challenge is assessed on the fourth day by the expert team, which also serves as a low-threshold personal introduction, asking questions about their design choices and difficulties, and how they implemented their ideas.

3.3 Post-course assignment

The final assignment is a personal reflection to be handed in as a 2-page report dealing with the following questions (learning objective D):

- ‘What are the current challenges in soft robotics?’
- ‘Can you give a recommendation for future research?’

We ask the student to answer these questions using the knowledge of their own research group and by incorporating the shared information and awareness that gained during the daily updates, discussion and expert presentations (learning goal 3). We also emphasize that, although the assignment is individual, their fellow students are now a source of expertise to discuss future research ideas. The deadline of this assignment is set to be 2 weeks after the final day of the course.

3.4 Student groups and evaluation of learning outcomes

For the research topics, the division into groups is based on their activity on the forum and videos (learning objective A). We tried to go for homogenous groups to ensure a good mix of nationalities and enthusiasm. The design teams, for the afternoon assignment, are created on the spot by a raffle. Therefore, students are continuously switching between groups after the lunch break and consequently strengthening the social cohesion. Students are permanently evaluated based on their design efforts for the Robogym challenges (objective B), their research progress (objective C) and a quotation on their final, individual assignment (objective D).
Additionally, based on a daily questionnaire, the research progress and design challenge is monitored, and at the same time the growth of the corresponding skills is charted to map in an informal way the individual learning outcomes. Here we do not focus on the summative scores of individual students but discuss their personal evolution based on daily self-reflections (Figure 3 and SI 3 & 4). Analog to Forbrig et al. (2022) students are asked to position their skill development (research and design skills) and team progress (research questions and design challenges) on a scale ranging from 0 (a novice with no expertise or no idea how to start) to 10 (feeling like an expert or research question/design challenge finalized). Additionally, their sentiment is tracked by emoticon indicators ranging from ‘happy’ (counts as +1 point), ‘neutral’ (0 points) and ‘sad‘ (counts as -1 point), which we use to adapt our daily mentoring. At the end of the week the students are asked how they experienced the educational setup. Also, the mentors (teaching assistants) and experts rate the students’ performances in a comparable informal way.

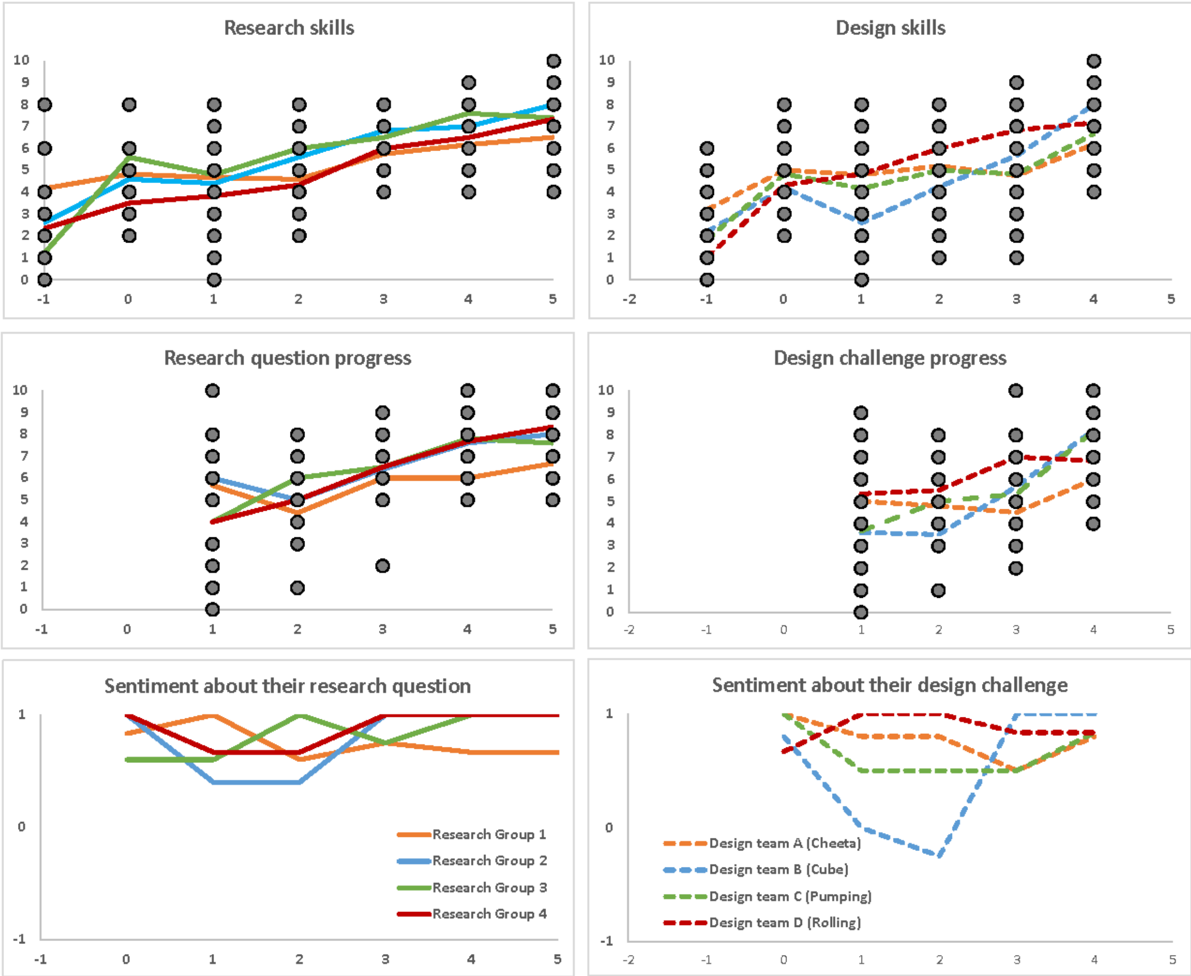


Figure 3: Self-reflection scores of the students, ranging from 0 to 10, are based on daily surveys. Sentiment scores range van +1 ('happy') to -1 ('sad'). Colored lines reflect the averages of the different Research Groups (1 to 4) and Design Teams (A to D). The horizontal axis codes represent the daily evolution (prior to the pre-course assignment and the start of the ATHENS week equals respectively -1 and 0, whereas 1 to 5 represent their self-reflections by the end of each day).

4 RESULTS AND DISCUSSION

4.1 Self-evaluation scores

After each discussion and design moment, we ask students to put themselves on an axis going from novice to expert about soft robotics and we aspire to see their level of expertness increase over time. The graphs indicate that students' skills and progress improve over time (figure 3 and supplementary data 3 and 4). All research groups and design teams have comparable upward trends in their scores and report a daily average increase in skills and progression in their efforts, although not all students indicate that they consider themselves as so-called experts by the end of the week. Confidence levels sometimes dropped within the design teams, related to limited progress that day, but rose even steeper within the following days. Based on the survey data and observations by the outside experts, we achieve our wanted level of expertise without creating the feeling of being lost or overworked. We do acknowledge that during the design phase students express fear of failing, frustration and limited success moments. We also realize that their personal judgements need to be better steered as some students overestimated their expertise levels during the first days. An additional questionary can be added at the start to help students better position themselves. Nevertheless, we hope by improving the skills of participants, and thus increasing their metacognitive competence, we help them to recognize the current limitations of their abilities. In addition, questions about group dynamics and their roles in the group functioning (e.g., leadership, …) could be a valuable addition.

4.2 Lesson learned from the prototype course

We aimed at an initial skill and knowledge development of soft robots by molding silicon rubbers (learning goal 1 and objective A). In our setup, the flipped learning concept by introducing the DIY package is accepted well by the students although experiments are not always successful and students hesitate to share their 'failed' molds on the digital platform, whereas others are proud of their success. This pre-learning outside the classroom paved the way for social interaction during the first day.

- We consider this first-hand experience successful as it acts as an incentive for students to learn, plus continue to learn, and boost their motivation
- As such, the learning outcome of goal 1 is positively evaluated for this part.

Learning activities of goal 2 facilitate on how to design, fabricate and control soft robots (theoretical approach). The theoretical part on day one starts with a general presentation on soft robotics and a critical self-reflection on the DIY molding experiments. The intention is to give a broad overview of the capabilities of soft robotics and their application potential, and ends posing the research questions that are essential in the field and thus the starting point for groupwork (learning objective B). Each group analyzes one of the essential research questions (see SI) and give a daily progress update to the peers. They have approximately 4 times 2.5 hours to do so, which is sufficient. With this we aspire knowledge and insight sharing between groups, helping them to advance during the next days, but also to ensure that they do not lose sight of the bigger picture. During the week, the mentors (professor and teaching assistants) are regularly available to the students, to ask critical questions, help them fathom research papers and instigate internal discussion. They are however not there to give answers and merely guided the students towards online sources (journal publications, conference recordings, research group websites, popular videos, etc.). At the last day, each group gives a final presentation, this time for the experts as well and start their preparation for the personal reflection (objective D).

- We notice that students need more preparation time the first day to understand the basic concepts and hypothesis related to their research question and are hesitant to start the proposed problem- and project-based setup. Even though we want to avoid classical lectures, we realize that a more structured starting point, levelling the understanding of basic concepts is beneficial and enable a better, more equalized, starting point for the research groups.
- Although we stated that the focus of this progress update is not on the form, but on content and concept, we notice that the first presentations (start of day 2) are presented as a literature study instead of a research hypothesis. Instructions were finetuned and during the final presentations, students focus better on the content and hypotheses, and are open for more discussion and opinions.
- We experience that these essential research questions have enough substance to broadly cover the basics of soft robotic technology, while allowing them to explore and understand the literature (objective C) and are capable of discussion

about state-of-the-art research (objective D). These trigger questions (see supplementary data) give them sufficient new insight to identify knowledge voids, that need to be further investigated. Furthermore, these daily triggers match their increasing skill-level throughout the week.

- Based on our experiences and interpretation, no further tweaking is needed for these (sub)questions and only more structure is needed at the start. The learning outcome of goal 2 is thus sufficiently reached as students were able to master a specific soft robot topic (learning objective 2).

For the design challenge in the afternoon (learning goal A, objective B), the learning outcomes were not fully reached. The obstacle run is considered as too difficult to achieve in one week and in fact limits student motivation during the intermediate days (see the drop in sentiment scores in figure 3) as their prototypes were for example not functioning on day two or failed during test runs on day three. A general observation, made by both students and mentors, is that students remain too long in a theoretical phase instead of experimenting with soft robot parts to figure out their preferred deformation of the soft parts (problem specification and implementation).

- Students and mentors report lack of focus and time during the afternoon sessions, thus more guidance and constraints are recommended. Less complicated design challenges are suggested and access to functional prototypes to learn by inverse engineering are an option to speed up the design process.
- Implementation of a deadline for a design concept, a showroom of demo models of actuators and daily progress updates, including a roadmap of intermediate goals and feedback moments, will be explored in the future. This will enable a better focus on controlling the behavior of the soft robot and as such, making more successful attempts during the Robogym demonstration.
- The key here is to fail faster and learn earlier, and by doing so, students will develop the necessary skills and knowledge for better problem definition/specification and thus increase their success rate by overcoming more or all obstacles.

4.3 Feedback from the students and the invited experts

Students particularly appreciate the self-paced learning atmosphere with a focus on growth-mindset, the teamwork experiences within an international network and being able to discuss with several senior experts, which explore frontiers of current knowledge (similar to the results of Forbrig et al., 2022). Many of the students have in-depth and original questions during the presentations at the last day, indicative of mastering the topic and openness for more awareness. The positive feedback from students indicate they learn a lot and gain confidence in their personal development of soft skills such as teamwork through discussion and co-creation, surprisingly also presentation skill improvements are reported as a side-effect. On a need-based perspective, our motivating teaching and learning opportunities, resulted in an autonomy supported learning setup in which students are very participative and mentors offer (meaningful) choices in how students deal with learning opportunities and optimally follow their pace (Alterman et al., 2019). Students like the daily structure and the presentations as intermediate goals, accessibility of the teaching assistants as mentors and the coworking-friendly learning environment in a high-tech collaborative room, which was praised regularly. Experts commented also positively regarding the students' performance, based on the research topic discussions and functionalities of the created soft robots.

5 CONCLUSIONS AND OUTLOOK

Although our setup is still within a development stage, the invited experts express their willingness to apply our educational shift. We expect to further finetune the concept by iteration within the network of soft robotics experts and transfer the setup to other courses. Therefore, we consider this educational approach, originally proposed by Forbrig et al. (2022), as a valid teaching method to achieve top-level effective learning as its generate strong dynamics, without an intensive didactical work load. Based on the positive feedback, our faculty wish to implement it for other ATHENS courses, plus promotion throughout our network to maximize learning experiences of students.

6 SUMMARY AND ACKNOWLEDGMENTS

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SUPPLEMENTARY MATERIAL

Research group 1: How to create an actuator for a specific functionality?

Day 1	Different actuation mechanisms
Day 2	Design spaces and how they lead to different force, stiffness & deformations
Day 3	Multi-modal actuators (stiffening, shape shifting & multi-actuation)
Day 4	Inverse design

Research group 2: How to control a soft robot that is interacting with its environment?

Day 1	Difference between hard and soft robots and implications to control strategies
Day 2	Feedforward control of soft robots
Day 3	Sensing of deformations through soft sensors
Day 4	Feedback/model-based control of soft robots

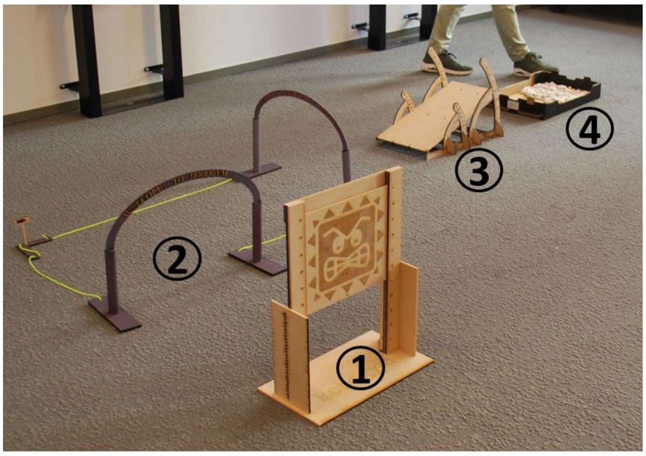
Research group 3: How to make soft robots at different length scales?

Day 1	Fabrication processes at the cm-scale and their limits
Day 2	Towards more complex architectures, by direct defining geometries
Day 3	Very small and very large-scale manufacturing
Day 4	Physics based manufacturing

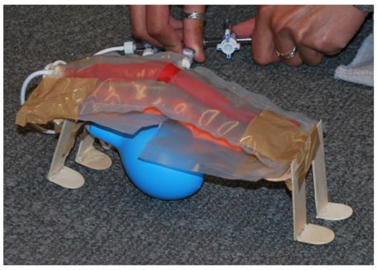
Research group 4: How to make soft robots untethered?

Day 1	The origin of tethers in soft robots
Day 2	Untethered soft robots by embodying energy
Day 3	Harnessing energy from the environment
Day 4	Embodied Intelligence as a way towards autonomy

Supplement 1: the essential research questions allocated to each research group, including the trigger questions per day.



1. Going under an obstacle, where the height of the clearance can be set
2. Take a 90° turn, where the radius of the turning circle can be set
3. Moving over an inclined surface, where the inclination angle can be set
4. Moving over a rough terrain, choosing between flat, sand, gravel and large stones



Supplement 2: setup of the Robogym challenge obstacle run and prototype soft robot

	prior	start	day 1	day 2	day 3	day 4	day 5
number of respondents (N)	22	22	22	19	19	22	22
				Research skills			
Research group 1 (av. score)	4,2	4,8	4,7	4,6	5,8	6,2	6,5
Research group 2 (av. score)	2,6	4,6	4,4	5,6	6,8	7,0	8,0
Research group 3 (av. score)	1,2	5,6	4,8	6,0	6,5	7,6	7,4
Research group 4 (av. score)	2,3	3,5	3,8	4,3	6,0	6,5	7,3
				Research question progress			
Research group 1 (av. score)	/	/	5,7	4,4	6,0	6,0	6,7
Research group 2 (av. score)	/	/	6,0	5,0	6,4	7,6	8,0
Research group 3 (av. score)	/	/	4,0	6,0	6,5	7,8	7,6
Research group 4 (av. score)	/	/	4,0	5,0	6,5	7,7	8,3
				Their 'feeling' about their research question			
'happy' (N)	/	19	15	12	17	20	20
'neutral' (N)	/	3	7	7	2	2	2
'sad' (N)	/	0	0	0	0	0	1
Research group 1 (av. score)	/	0,8	1,0	0,6	0,8	0,7	0,7
Research group 2 (av. score)	/	1,0	0,4	0,4	1,0	1,0	1,0
Research group 3 (av. score)	/	0,6	0,6	1,0	0,8	1,0	1,0
Research group 4 (av. score)	/	1,0	0,7	0,7	1,0	1,0	1,0

Supplement 3: Self-assessment scores of the research skill development and research question progress.

	prior	start	day 1	day 2	day 3	day 4	day 5
number of respondents (N)	22	22	22	19	19	22	/
				Design skills			
Design team A (Cheeta; av. score)	3,2	5,0	4,8	5,2	4,8	6,2	/
Design team B (Cube; av. score)	2,2	4,2	2,6	4,3	5,7	8,0	/
Design team C (Pumping; av. score)	1,8	4,8	4,2	5,0	4,8	6,7	/
Design team D (Rolling; av. score)	1,0	4,3	4,8	6,0	6,8	7,2	/
				Design challenge progress			
Design team A (Cheeta; av. score)	/	/	5,0	4,8	4,5	6,0	/
Design team B (Cube; av. score)	/	/	3,6	3,5	5,7	8,2	/
Design team C (Pumping; av. score)	/	/	3,7	5,0	5,3	8,2	/
Design team D (Rolling; av. score)	/	/	5,3	5,5	7,0	6,8	/
				Their 'feeling' about their design challenges			
'happy' (N)	/	19	16	13	14	19	/
'neutral' (N)	/	3	4	3	4	3	/
'sad' (N)	/	0	1	3	1	0	/
Design team A (Cheeta; av. score)	/	1,0	0,8	0,8	0,5	0,8	/
Design team B (Cube; av. score)	/	0,8	0,0	-0,3	1,0	1,0	/
Design team C (Pumping; av. score)	/	1,0	0,5	0,5	0,5	0,8	/
Design team D (Rolling; av. score)	/	0,7	1,0	1,0	0,8	0,8	/

Supplement 4: Self-assessment scores of the design skill development and design challenge progress.