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Santa has Everything under Control: A Control Themed Advent Calendar

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Abstract: We describe the process of creating a control themed advent calendar quiz by means of a joint effort of researchers involved in control education from different countries, of distributing it among our students, and of collecting and analysing feedback from who answered the quiz. The created calendar consists of 24 problems, one for each of the 24 days before Christmas, and has been proposed to university students with the aim of showing them the many aspects that control engineering touches upon, and how this discipline can be useful in a wide variety of applications. We thus discuss the lessons learned from carrying on this initiative, with the purpose of aiding the creation and management of similar ones by listing what we believe are good practices in collaboratively creating quizzes, and in general what we believe may improve control education and serve as a valuable measure for outreach.

Keywords: Control Education; Gamification; Outreach

1. INTRODUCTION

Despite being crucial across various industries, control engineering remains unfamiliar to the majority, including engineering students. Unlike fields like big data and artificial intelligence that receive media attention, control engineering, with its governing principles, is often overlooked. Emerging technologies involve increasing control, making it essential for the general public, especially engineers, to grasp basic concepts related to feedback and control. As control-oriented teachers, it is our task to dispel the perception that control is dull, remote, and incomprehensible, by engaging and convincing engineers of its significance.

We even observe a low and decreasing interest from students to take control subjects and a worrying low and decreasing amount of people choosing to study Science, Technology, Engineering and Mathematics (STEM) in many western countries, see also the discussions in Johnson and Jones (2006); Shapiro et al. (2015); Greaves (2019). Hence, a variety of outreach activities are undergone to attract more students to STEM, (Draughn and Rinehart, 2000; Dubetz and Wilson, 2013), including outreach activities specially for control engineering (Jackson et al., 2021; Knorn et al., 2021).

We believe that the low and decreasing interest in STEM and control in particular is related to the abstract nature of control. The very strength of control, i.e., being able to describe and tackle a vast variety of different applications with the same universal and abstract mathematical approach, is also among the largest hindrances to comprehend the concepts and connect them to relevant technical problems. Understandably, this contributes to the perceived lack of engagement in control courses.

We try to alleviate this problem by creating a fun, engaging and accessible way of learning about and being exposed to control engineering by developing a control themed advent calendar for 2023. Similar advent calendars exist in different fields already, e.g. in math (Mathe im Advent / MATH+ Adventskalender, 2023; Känguru-Adventskalender, 2023; Iannella et al., 2021), physics (Physik im Advent, 2023) and programming (Advent of Code, 2023). These calendars have in common that participants are confronted with a small challenge or problem every day from the 1st until the 24th of December. The questions/challenges are related to a principle or concept in math, physics, programming or similar but usually do not require familiarity with that principle or concept at all, often enough not being even mentioned in the question itself, but only in the solution given afterwards. Participants then seek to solve the challenge (often a multiple choice question) by reasoning, experimenting or pure guessing and enter their answer into a designated online platform. One can win by answering as many questions as possible correctly, in case of draws the accumulated time used for answering can be used as well.

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We believe that this will in general be perceived as a fun and unusual way to get exposed to automatic control. Being condensed into a relatively short time during the year, it is likely manageable more easily (in the sense of administering it, and collecting the information from the players) for otherwise usually busy academics. Moreover, the calendar does not require any physical equipment (compared to other gamified approaches to teach control, e.g., an escape room (Axelson-Fisk et al., 2022)) or dedicated software (compared to a game developed (Münz et al., 2010)) and can hence potentially reach participants beyond the typical group of local students.

Of course, the concept is not limited to an advent calendar. Any season leading to a holiday may be a good occasion to undergo a similar activity. The advent calendar was chosen due to the cultural background of the authors and the general popularity of similar advent calendars in many western countries. In this paper, we thus:

- describe the general idea and concept behind the control advent calendar (Section 2);
- describe how questions were formulated and the difficulties encountered while doing so, as well as provide some concrete examples (Section 3);
- share some lessons learned from implementing the control advent calendar in December 2023 (Section 4);
- draw our conclusions and suggestions for future iterations (Section 5).

2. CONCEPT AND GENERAL SETUP

The concept of a thematic advent calendar shares similarities through different disciplines such as math (Mathe im Advent / MATH+ Adventskalender, 2023; Känguru-Adventskalender, 2023), physics (Physik im Advent, 2023) and programming (Advent of Code, 2023): each day from the 1st until the 24th of December, a "door" opens, revealing a (multiple choice) question or challenge.

In contrast to a test, the questions are somewhat fun or even quirky, and are meant to be amusing and engaging. Being an advent calendar, the questions are also embedded in a story containing Santa Claus, reindeer, elves or other magical/mythical creatures associated to Christmas. Some calendars only require reasoning and some simple calculations (Mathe im Advent / MATH+ Adventskalender, 2023; Känguru-Adventskalender, 2023). Others require conducting small experiments with every-day-items (Physik im Advent, 2023).

Participants get access to the questions, including instructions to experiments if applicable, through a web portal where they also submit their answer. Each day a new question becomes available. To ease the scoring of such questions, these are typically multiple-choice, and participants may only enter their answer once. After entering the answer typically the players receives also the correct answer, including an explanation or worked out solution. Note once again that typically there is no possibility to alter one's answer. For nationwide (or even beyond) the people with the most correct answers (and having been the quickest overall in case of a draw otherwise) are named, so that having ones (nick-)name or username displayed is the awarded prize.

The difficulty ranges from targeting primary school students (Känguru-Adventskalender, 2023) to high school students (Mathe im Advent / MATH+ Adventskalender, 2023; Physik im Advent, 2023), and up to university students (Advent of Code, 2023). When addressing participants before undergoing tertiary education, the questions are formulated in the local language, e.g., German (Mathe im Advent / MATH+ Adventskalender, 2023; Känguru-Adventskalender, 2023; Physik im Advent, 2023); while for university students, English may be used even in non-native settings (Advent of Code, 2023).

For the control advent calendar, a group of control academics worldwide joined to create the (to the best of our knowledge) first international control themed advent calendar. The involved universities were located in France (CentraleSupélec, Université Paris-Saclay), Germany (TU Berlin, HAW Hamburg), Italy (University of Brescia), Norway (NTNU and University of Stavanger), Panama (Universidad del Istmo), Spain (University of Almería), and UK (The University of Sheffield).

Each of the participating teachers contributed a small number of questions and relative solutions, written in English (see Section 3 for more details). The questions were edited in LaTeX via an online collaborative writing and publishing platform, and shared among the participating academics so that each might create a local version of the quiz in their learning management system, enabling their own students to join. Some (even if not all) of the creators moreover translated the questions into their native languages, e.g., to German, with the hope of maximizing participation. Indeed some students may be hesitant to join the calendar if fearing to struggle with the questions not only due to the difficulties in control but also for a lack of appropriate English vocabulary. As discussed in Section 4 below, these effects may indeed play an important role.

We also noted that creating a digital solution to allow participants to see and answer the questions proved much more difficult than expected. As there was not enough time to setup a dedicated website for it, like in Mathe im Advent / MATH+ Adventskalender (2023); Känguru-Adventskalender (2023); Physik im Advent (2023); Advent of Code (2023), we opted for creating modules/courses on our individual universities learning management systems, i.e., Canvas, Moodle, and Blackboard. While this allowed for a rather fast implementation of the calendar as the digital infrastructure handled enrollment, settings (e.g., when questions are displayed and limiting the number of attempts) and collecting the number of correct answers in the end, unfortunately it only allowed local students to join. That means, e.g., that only people enrolled or working at TU Berlin could join the calendar in Berlin. Thus, despite the questions being designed to be accessible to people without an engineering / control engineering background and from outside university, due to this administrative issue, the reach was mostly limited to local students whose academic history contained control topics.

Finally, we note that some of the organizing teachers organized some local prizes for the best participant(s), with the aim of promoting participation. For example, at TU Berlin, three prizes were given out: 1) playing the control themed escape room (Axelson-Fisk et al., 2022),

2) a knitted set of pot holders made by the professor (S. Knorn) and 3) a box of chocolate. At the University of Brescia, the grade of an exam was increased for the winner. Gingerbread houses and chocolate advent calendars were awarded at the University of Stavanger. The University of Almería provided a double prize, with 0.5 extra points in the final grade and a 3D printed desktop support for a mobile phone decorated with the research group and university symbols. The prizes were chosen to have little to no economic value to not undermine the expected intrinsic motivation to participate.

3. QUESTIONS

The decision of creating the questions was taken collegially at the end of October 2023. After some initial discussions, and before starting the actual process of drafting the structure of the calendar, we thus decided that the questions should aim at achieving the following goals:

Close to everyday life: All questions should be embedded in a story about some problem that is relevant to the supposed everyday life of Santa or the elves, while being also applicable to ordinary situations.

Fundamental concepts of control: Each question should deal with a fundamental principle in automatic control, while being potentially accessible to people with little or no background in control. We decided to focus the biggest part of the quiz on the contents of a typical first control course, following the indications from Rossiter et al. (2020). We though also introduced questions related to more advanced concepts, but only if they could be tackled using intuitions and without mathematical derivations. In more details, the 24 questions covered the following underlying principles: 1) steady state value; 2) linear time invariant systems, linearity of the response; 3) ratio control; 4) aliasing; 5) superposition effects in linear time invariant systems; 6) stability margins; 7) control of non-minimum phase systems; 8) steady state error in proportional control; 9) feedforward; 10) stochastic systems; 11) all-pass / non-minimum phase zero; 12) integral control; 13) Nyquist criterion and phase margin; 14) deadtime systems; 15) Petri net with deadlock; 16) aliasing; 17) PID tuning; 18) Petri net modelling; 19) trajectory planning; 20) unstable system in parallel to stable system; 21) integral action; 22) windup; 23) disturbance response; 24) poles and stability.

Enhance an enjoyable experience: All questions should be funny or contain some amusement. They could also be a bit nerdy or quirky, but that was not a must (and if so, we argue that it might rather is due to some engineering culture related quirkiness). If possible, the potential answers were also tweaked to be funny.

Christmas themed: Since we were creating an advent calendar, the questions were one way or another related to Christmas. This was easily achieved by including Christmas-related characters, objects, locations and activities (e.g., Santa and elves, Santa's sleigh, Santa's workshop, baking cookies, producing gifts, flying a sleigh, etc.). Actually this setup helped formulating the questions in a few questions, since we could fall back to magic to motivate situations where not all physical laws applied. To make an example, a reindeer may indeed show unstable behaviour and become infinitely fast without control – a feature not often observed in reality.

Multiple-choice: All questions were formulated as multiple choice to allow for automatic processing of the answers. All the questions (but the 24th) had only one correct answer. Choosing non-obvious wrong answers is a difficult but important task to make sure a clever or well thought through question is not undermined by the possibility to simply ruling all wrong answers out due to them being non-plausible or obviously wrong. Moreover, in contrast to official tests and exams where we typically ask only serious questions, we added some obviously wrong but funny answers, to make the whole experience more enjoyable.

Accessibility: We initially strove for enabling people with little or no control background to enjoy and answer the questions. It was thus deemed of utmost importance that no control language was used in the questions, or at least not necessary to correctly answer them. We especially went for restricting the usage of formulas or notation. Also, the questions were formulated such that as little as possible (preferably none) prior control knowledge was required.

A posteriori, achieving the first two identified goals (i.e., formulate questions that are close to everyday life, and address some fundamentals of control) was relatively easy, likely because we already tend to follow these when creating ordinary exams and exercise questions. Achieving the "be funny" and "be Christmas themed" goals was relatively easy too, even though these are not typical goals when creating questions. Writing questions in a multiple-choice format proved somewhat difficult, especially when considering the need for good, non obvious wrong answers (a typical challenge when creating this type of questions).

The main difficulty we experienced when creating this advent calendar was instead formulating them technically correct without using control lingo, and with solutions that were computable without using control oriented formulas. In some cases, we opted for describing what formulas or control specific terms would have otherwise summarised in a few symbols or words into descriptive sentences. Unfortunately, this made the questions become sometimes somewhat lengthy. On the one hand, this created a good opportunity to include little side notes and funny details; on the other hand, though, this increased the risk of obfuscating important details, as they became embedded in more text that may contain actually irrelevant information for the purpose of finding the correct solution.

Not too surprisingly, some students complained about this issue (wordy/long questions) in their feedback. Some also mentioned that due to the wording (instead of formulas) some aspects were unclear or perceived as misleading. However, the authors deem this issue also to be a potential strength/benefit of the questions. In reality, when engineers are confronted with a practical problem to solve, the problem statement seldom comes in form of a well thought through, precisely formulated question including all required details and no unnecessary information. Hence, in this sense, being able to extract control relevant system information and formulate the problem in a technical manner is a key ability, which we believe can (and must) be trained. Paradoxically, this issue likely made it harder for people with control background as they had to convert the

text into mathematical formulations common in control to feel "at home", while we believed it may allow people without such background to relate and comprehend the questions better. Hence the amount of technical lingo to be used introduces a tradeoff that should be kept in mind when designing initiatives such the here presented one.

Finally we remark that all questions also contained worked out solutions or explanations of the correct answer, that were displayed after having entered a solution. In those, some control formulas were embedded in order to save space and be more precise. In some cases, participants were also encouraged to further read about the tackled concept and additional literature was cited.

To make the remarks above more concrete, we here include three example questions from the advent calendar:

Question 8

Santa Claus relied on his trusty reindeer to achieve a speed of 88 miles per hour to ensure the timely delivery of all the gifts. However, the reindeer had the peculiar habit of consistently falling short of Santa's speed target, always reaching a speed precisely ten times the difference between the desired speed and their current pace. Fully aware of this curious fact, Santa exclaimed, *"Ho ho ho, let's aim for 95 miles per hour!"* Did every child receive their presents that magical night?

(a) Yes, and Santa would even have quite some extra time to enjoy a bottle of Koskenkorva * .
(b) Yes, but just in time.
(c) No, the reindeer would fall just a bit short of the target.
(d) No, most children in the world would not receive presents at all.
(e) No, I don't believe in Santa.

Proposed solution: Correct answer is (c). Indeed, according to the question, the reindeer would reach the velocity:

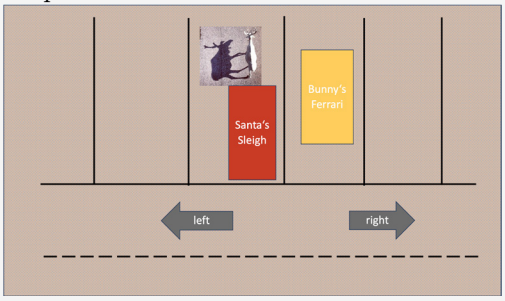
$$v = 10\,[r - v] \quad \Rightarrow \quad v = \frac{10}{11} r$$

Unfortunately, when $r = 95$ mph, the reindeer would reach a speed of 86.4 mph, which falls just a bit short of the target required to activate the flux capacitor and ensure that every child receives their present.

* Traditional clear spirit drink (38%) in Finland.

Question 11

Santa is in a rush, and parks his red sleigh in forward direction in a parking lot, leaving it perpendicular to the road and left from the yellow Ferrari of Bunny, the Easter rabbit. Santa knows it will be a mess to get old Red Nose out of the lot when he will be back, but he has to deliver all these funny electronic devices (no idea what "PID" on the parcel should mean)!
After the delivery he goes back, and he is relieved to see there is no Ferrari in the lot. But arriving to the sleigh he discovers a nasty bump at its right door, and a reasonable bit of yellow color. He thinks *"Bunny is always too fast and careless! But this time he will pay for the damage!"*.
Santa thus decides to fill up the form for getting refunds from the insurance, and on page 1 he is asked to report a drawing of the situation. Unfortunately, he did not remember whether the Ferrari was parked forwards or backwards. Moreover, it is not clear to Santa whether Bunny had left the parking lot to the right or the left of the road. Can you help him reconstruct the situation?



(a) Bunny's Ferrari was parked forward and he drove to the right.
(b) Bunny's Ferrari was parked forward and he drove to the left.
(c) Bunny's Ferrari was parked backward and he drove to the right.
(d) Bunny's Ferrari was parked backward and he drove to the left.
(e) Santa knows for sure that Easter rabbit does not exist.
(f) Bunny is not responsible because he has lost his driving license due to unexpected striking of hooks.

Proposed solution: Correct answer is (b). Because the color mark is at the door, it is somewhere in the middle of the right side of the sleigh and not at a corner. If the Ferrari would be parked backwards, parking out means front wheel steering whereas if forwards, it will be a manoeuvre with rear wheel steering. The second is known to be non-minimum phase, i.e. with zeros in the right half of the complex plane. This has several consequences and can cause accidents! In this case, Easter bunny was heading to the left of the road in forward gear. For this, he needs to drive out of the lot to the right in backwards gear. Because of the non-minimum phase behaviour, although he ends up his backwards turn by standing pure right of Santa's

sleigh (DC gain), there is a phase of the movement, where the left front wheel and chassis are moving to the left - before going to the opposite direction, which is classical behaviour of non-minimum phase systems. In this phase, the Ferrari has hit Santa's sleigh in the middle. If the Ferrari would have been parked backwards, a hit at a corner would be possible (but less likely because of minimum-phase behaviour). Nice paper considering the problem for 2-wheel vehicles: `https://ieeexplore.ieee.org/document/1499389`

Question 24

Which pole is stable?

(a) What do I know?! I thought this advent calendar is about control and not geography?
(b) Of course, NP = Not stable Pole and SP = Stable Pole.
(c) Due to global warming, the ice at the north pole is melting (unstable), whereas Antarctica is a continent and cannot melt away (stable).
(d) Of course, the north pole is unstable because it is located in the right half plane, whereas the south pole in the left half plane is stable.
(e) Doesn't matter too much - in any case these two poles show that the world is complex.
(f) I'm unsure about this, so I'm planning to take some control courses in 2024 to learn more about it.

Proposed solution: Each answer will score a point, since each of them is correct. Thank you for participating. Merry Christmas!

4. LESSONS LEARNED

4.1 The creation process was started too late

Creating questions was started in late October 2023 with the objective to have all questions ready by the second half of November and everything ready and implemented by November 30. This proved to be extremely late and hence created quite a bit of late and after hour work. At the beginning we thought that having a month would have been enough to create two questions per each of us. All the authors were though inexperienced in creating questions without control notation and formulas and hence the creation of the questions took way more work than expected and planned. Some questions were indeed reworked and reformulated by different participating academics to achieve the desired goal several times. Despite the imminent stress and deadline pressure (the last two questions were only finalised by 20th December, just to give some context), creating the questions was also perceived as the funniest part of the project. In fact, that was a main motivation to participate in the creation over all. In a job with a high amount of not primarily enjoyable and dull tasks, being invited to work on something funny, unusual and creative was an appreciated change from the ordinary. Yet, for future runs, one should start significantly early to create and collect questions without increasing the stress levels.

4.2 Avoiding using technical lingo is non-trivial

As mentioned above, making questions without the lingo and wording usually used in exam questions proved to be more difficult than expected. Regular exam questions cannot be used straight away but some participating academics may use some of the questions from the calendar in their future exams. Indeed, formulating questions very differently from the usual way also allowed for new ways of seeing and describing control problems.

4.3 Canvas, Moodle, Edunao and Blackboard currently seem less interoperable than they advertise

It was originally planned to first write all the questions via an online shared LaTeX document, then import them in one of our learning management systems, then export them as a .qti file (i.e., a XML document implementing the *Questions & Test Interoperability* standard), since this would nominally enable the others upload the questions without efforts in the own system. This strategy would thus nominally automate the conversion of the questions into a format usable for Canvas, Moodle, Edunao (Moodle-based platform) and Blackboard. Unfortunately, this did not work out as planned at all as for many of us importing the .qti file created irreparable errors messages. Hence, as a workaround, that unlucky participating academics for which the .qti standard was not working had to copy and paste the text bits into the own teaching portal by hand. This issue could have been dealt with different stress, and potentially with more testing of different standards, but at the end the main culprit we believe should be given to the existing learning management systems.

4.4 There exists the need for a platform that enables anybody potentially sign up for this type of events

Similar to the technical issue above, we found it difficult to implement a truly public advent calendar where participants from around the world can register and answer questions, for which each question can be answered only once, for which the questions appear automatically at 10am local time each day, and for which the answers are graded automatically by the system. Being able to do something like this without requiring a university login is an unsolved question.

There might exist suitable online solutions to this, but to our experience they must be tested properly beforehand. Among the potential solutions we identified, the likely best one was the one tested by CentraleSupélec, where the teacher used Wooclap (2015). Investigating a perennial

solution took some time, and therefore, the students participating in this project at CentraleSupélec received the calendar in a different form on December 24 as a gift from Santa called "Santa's funny quizzes on Control". Thus, the students received all 24 questions in a single link. Moreover for these students the quiz was entirely optional, potentially anonymous, and possibly administered at the own pace. In other words, the quiz created in Wooclap allowed students to answer questions when they want during their 2-week winter holidays. We remark that Wooclap currently offers numerous features for more interactive quizzes than the ones we implemented in the advent calendar (e.g., label an image, find on an image, matching, sorting, etc.), options that we plan to consider in the next iteration of the calendar. Most importantly though, Wooclap offered the possibility to easily spread the calendar via a weblink, meaning that it could be possible in the future to embed the quiz on a web page and deploy it at a large scale, also laddering on social media based advertisement.

4.5 Advertising should be done in a timely matter

Our first motivation was to create the advent calendar as an outreach activity. We though found that most participants were students currently taking our courses, likely also due to our lack of timely advertisement through other channels than direct contact to our students. For instance, at TU Berlin, the press office was hesitant to release a press issue due to the calendar not being available to the wider public. Hence, starting the creation of the advent calendar much earlier and putting an emphasis on finding a technical solution independent from university teaching portals should be a priority in the future.

We also note that a possibly important factor that may work as an advertisement (and encouragement for participation) may be acknowledging students' participation by including the result/participation in their europass-valet (see `https://europa.eu/europass/en`).

4.6 Language barriers may matter

Last, our intuitions says that translating the questions in the local native language other than English is potentially very important. In a test case at TU Berlin the advent calendar was offered in English and the native language (German). Despite a pretty international body of students, there were much less students enrolling and staying on in the English version compared to the German one. However, too few data are available to currently draw a definitive conclusion on this matter.

5. CONCLUSIONS

We discussed the process of creating an outreach initiative that was not funded by any body, but rather was born in a grassroot fashion following our desire to create something fun for our students, and interesting for the general public.

We listed the difficulties we encountered, and the organizational mistakes we suggest to avoid in the next iterations of the initiative, that we summarize in: (i) start the creation of the material much earlier, (ii) start advertising the initiative earlier too, (iii) if you think that creating funny questions involving math but written with non-technical language is easy, well better if you think again at it, (iv) finding a suitable software platform to host the initiative is not trivial. Especially related to the last point, we believe that more time should be spent on finding alternatives to university teaching portals, since the latter have been a limiting factor for our outreach effort.

Despite these problems, the feedback from the participants overall has been positive, and the experience of creating this advent calendar has also strengthened the ties among the creators. Overall, we assess this as a positive experience to be repeated next year, hopefully becoming a tradition.

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REFERENCES

Advent of Code (2023). adventofcode.com.

Axelson-Fisk, M., Gentsch, M., Jackson, R. R., Knorn, S., Paasche, L., Topalovic, D., and Voit, S. (2022). Ctrl+esc: An escape/exit room to teach control and its relevance to an audience outside engineering. *IFAC-PapersOnLine*, 55(17):255–260.

Draughn, P. and Rinehart, J. (2000). High School Outreach Program (HOP). In *WEPAN 2000 National Conference, Second Stage Transformations*.

Dubetz, T. and Wilson, J. A. (2013). Girls in Engineering, Mathematics and Science, GEMS: A science outreach program for middle-school female students. *Journal of STEM Education: Innovations & Research*, 14(3):41–47.

Greaves, L. (2019). Key trends among STEM graduates.

Iannella, A., Morando, P., Spreafico, M. L., et al. (2021). The advent calendar: A university experience for spacing learning, practicing math, and enjoying studying. In *HELMeTO*.

Jackson, R., Knorn, S., and Varagnolo, D. (2021). An outline of the story of girls in control and its success in motivating girls internationally. *IFAC-PapersOnLine*.

Johnson, W. C. and Jones, R. C. (2006). Declining interest in engineering studies at a time of increased business need. In *The Glion Colloquium*.

Känguru-Adventskalender (2023). www.mathe-kaenguru.de/advent.

Knorn, S., Jackson, R., and Varagnolo, D. (2021). Girls in control: Reaching out with control. *IEEE Control Systems Magazine*, 41(4):16–18.

Mathe im Advent / MATH+ Adventskalender (2023). www.mathekalender.de.

Münz, U., Böhm, C., Eck, J., Reble, M., Schumm, P., and Allgöwer, F. (2010). A matlab-based game for advanced automatic control education. *IFAC Proceedings Volumes*, 42(24):140–145.

Physik im Advent (2023). www.physik-im-advent.de.

Rossiter, J., Serbezov, A., Visioli, A., Zakova, K., and Huba, M. (2020). A survey of international views on a first course in systems and control for engineering undergraduates. *IFAC Journal of Systems and Control*.

Shapiro, H., Østergaard, S. F., and Hougaard, K. F. (2015). Does the EU need more STEM graduates? Technical report, Danish Technological Institute.

Wooclap (2015). www.wooclap.com.