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# Experiences with using Kahoot! in control theoretical courses

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***Abstract*— Kahoot! is an online learning platform used to play and share interactive learning activities, quizzes, and questions. This paper presents the experiences with using Kahoot! in control theoretical courses at the University of Stavanger, Norway. An example of how to use Kahoot! within a 2-hours review of the Laplace transform is detailed. The discussion is supported by quantitative and qualitative data collected through a questionnaire and by the lecturer's own reflections after reviewing the feedback received during the final course evaluations. The content of this paper can be relevant for lecturers of automatic control and other STEM-related courses that want to make a more extensive use of Kahoot! as an active learning tool that stimulates and engages students.**

## I. Introduction

What does it mean to study control theory today? Nowadays, we are immersed in the digital world, where all types of information are available and it is up to each user to assess its veracity and use it for different purposes. At the end of 2022, the spreading of the large language model-based chatbot known as *ChatGPT* has given to each one of us our own C-3PO companion and revolutionized the way we fetch information and acquire knowledge. Through this tool, people obtain answers to *all* their questions, not necessarily correct answers though, since some of them would be totally wrong or at least cause one to raise an eyebrow. In the future, the ability to assess the quality of retrieved information will be of greater importance, and the level of knowledge of each individual will play a bigger role in it.

Taking all this into account, are we prepared to adapt the way we deliver our courses to new times? In July 2023, a panel session entitled *What should control education look like in 2030?* was organized at the 22nd IFAC World Congress, where the speakers discussed the challenges, the changes, and the measures to implement that automatic control lecturers should keep in mind to ensure that their students remain not only motivated but also participatory and creative throughout the academic term. They talked about the roadmap in the control education community [11] in which it was pointed out that a key element to stay at the forefront of what is happening in this new digital era is for teachers to adapt to the students. For example, recent studies have pointed out that students understand and can remember complex concepts much better when they are exposed to videos than when being exposed to traditional resources, such as textbooks, class lectures and handouts [1]. The results in [6] show that the best learning performance is achieved when using relatively short videos, with a suggested optimum length for a lecture or a tutorial video being between 6 to 10 minutes for engineering students. These findings are valid for the majority of students, and lecturers must be aware of this when planning their activity and the instructional teaching tools to be implemented.

It is for this reason that in the last few years, some major changes have been introduced in the courses *ELE320 - Control Systems* and *ELE620 - Cybernetics* offered by the University of Stavanger, with the aim of maintaining the essence and learning outcomes of these subjects, while at the same time delivering them in an interesting and engaging way that makes the students feel more motivated and curious. The students from these courses have expressed in several occasions that the Kahoots are a particularly appreciated innovation. Kahoot![1] is an online learning platform used to play and share interactive learning activities, quizzes and questions. They have been widely used in certain areas of education, as discussed by [14], which after reviewing 93 papers concluded that Kahoots demonstrated to have a positive effect on learning performance, classroom dynamics, students' and teachers' attitudes, and students' anxiety. The literature review [15] built on previous studies and examined how Kahoot affects learning outcomes and collaboration in the classroom. It was concluded that Kahoot can improve the interaction between students and teachers during the lecture, as well as inspire extracurricular collaboration among the students.

It is worth mentioning that the inclusion of Kahoot as a formative assessment tool in Control Systems lectures was described by [7]. In [7], one pool of four questions (in average) was applied at every lecture, usually at the end or whenever a principal subject was introduced. The results obtained using a questionnaire indicated that the students identified *more interactive lectures*, *better assessment of what I have/have not understood* and *receiving instantaneous feedback relative to my degree of knowledge* as the main advantages for using Kahoot in lectures. Conversely, *class agitation during these activities*, *need to have a compatible and functional device in classes* and *questions are always multiple choice* were identified as the main disadvantages. Notably, most of the students thought that *Kahoot should also be used in problem solving classes*.

The present paper shows how Kahoot can be used as the core around which entire lectures are built. By using the functionalities offered by a premium account, i.e., different

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[1]Note that the exclamation mark will be omitted in the rest of the paper.

types of questions, one of the drawbacks described by [7] is addressed. Notably, the students can also submit open answers that spark for discussion, thus making them active participants of the lecture. We also show that a traditional (long) exercise can be fragmented into several atomic questions following a divide-and-conquer approach, thus enabling the use of Kahoot in problem solving classes. Moreover, memes, wordplays and AI-generated content can be included in the Kahoot to make the lecture more entertaining, which has the benefit of increasing the attention span of the students.

The remaining of the paper is structured as follows. Section II describes the courses ELE320 and ELE620 and the different instructional teaching tools that are currently implemented. Section III provides an example of how Kahoot can be used as the core around which a 2-hours lecture which reviews the Laplace transform can be built. Section IV discusses the experiences with the use of Kahoot in control theoretical courses, with the support of collected quantitative and qualitative data that provide insight into the students' opinion and perception. Finally, Section V draws the main conclusions and discusses open issues.

## II. Control theoretical courses at the University of Stavanger

The experiences collected in this paper refer to the courses *ELE320 - Control Systems* and *ELE620 - Cybernetics* at the University of Stavanger. The first author of this paper is the responsible and main lecturer for both courses. ELE320 is part of the curricula of the Bachelor in Control Engineering and Circuit Design and the Bachelor in Energy and Petroleum Engineering. Most of the about 100 attendees are second year students. ELE620 is an elective course in the Master in Robot Technology and Signal Processing, with approx. 10-15 second year students each year.

Both courses correspond to 10 ECTS with a total expected student workload of 250 hours. ELE320 covers six different topics, mostly related to the classical Laplace-based analysis and design: (i) Modelling of dynamical systems; (ii) Analysis in the Laplace domain; (iii) Introduction to feedback control; (iv) The root locus; (v) The frequency response; and (vi) Introduction to the state-space. On the other hand, ELE620 covers six topics, mostly associated with the modern state-space perspective: (i) Introduction to state-space modelling; (ii) Linearization and stability; (iii) Discretization; (iv) State-feedback and optimal control; (v) State observers and Kalman filtering; and (vi) Parameter estimation. Furthermore, different instructional teaching tools are implemented:

- **Asynchronous pre-recorded lectures:** the students are given pre-recorded lectures consisting of videos with a usual length between 10 and 30 minutes, although exceptions to this rule are made when deemed convenient. Among the provided videos, there are the well-known *Control System Lectures* by Brian Douglas [2].
- **Synchronous lectures:** these correspond mostly to the traditional frontal teaching. An exception, however, are the so-called *Kahoot'ified lectures*, which are 2-hours long lectures focused on a Kahoot quiz to revise the content of previous lectures. These Kahoot'ified lectures are the main topic covered by this paper.
- **Homework assignments:** individual assignments that contain problems related to the content covered in the lectures. These assignments contain a mix of traditional lectures to be solved *paper-and-pen* (the use of symbolic aids such as Wolfram Alpha is encouraged, in agreement with their marketing phrase *Stop teaching calculating, start teaching math* [9]), MATLAB/Simulink exercises and open questions that incorporate the ready-to-use simulators developed by UNED [5].
- **Laboratory assignments:** the students use physical equipment available at the university (a two-tank system [13] and Quanser devices such as the Aero [3], which mimics the aerodynamical behavior of a helicopter) to solve group-based assignments which constitute a bridge between theory and practice.
- **The Control Zendo boardgame:** the course ELE320 incorporates gaming sessions using the Control Zendo boardgame [12]. Participation to these sessions is on a voluntary basis, but doing so counts as an approved homework assignment, with the students also getting free pizza out of it, which is a nice combo.

## III. Example: Reviewing the Laplace transform with a 2-hours Kahoot

This section describes a 2-hours Kahoot'ified lecture which reviews the Laplace transform, the transfer function and the use of partial fraction expansion to get back from a given $Y(s)$ to the corresponding $y(t)$.

After a short introduction of the topic, and having provided the students with enough time to enroll into the Kahoot, the questions can start. For each question, the corresponding time limit is provided.

***Question 1 - What is the Laplace transform? What is it useful for? (90 s)***

This is an *open-ended* question, which comes accompanied by the meme shown in Fig. 1, where players type their answers as free-form text up to 250 characters. Their answers are visualized as text cards, and they are not awarded points. Hence, the students are free to answer as they like, and the anonymity provided by the text cards make the students provide answers of all types, such as[2]: *not sure*; *don't really know what it's useful for yet*, *it's useful for solving differential equations*, *linerazation of models for all kinds of systems*, *using final value to find DC gain*, *dynamic respons of a system*, *easier to make calculations*, *tool*, *Laplace function change $F(s)$ to $f(t)$ and vice versa*, *an integral transform that Canberra a function of a real variable to a function of a vomplex variable*. These answers form the basis for further discussion, where the lecturer can state that "*don't worry, if you don't know what the Laplace transform*

[2]Spelling mistakes are preserved when listing the submitted answers.

*is useful yet, you'll discover it in the upcoming weeks*", while at the same time acknowledging correct answers, and even admitting of not being sure whether a given statement was right or wrong, as in the case of the Canberra-related answer...


Fig. 1. Meme for Question 1, taken from r/EngineeringStudents subreddit, posted originally by the user u/amr5120.

***Question 2 - What is the definition of the Laplace transform? (60 s)***

In this *quiz* question, four possible definitions of the Laplace transform are provided, and points are awarded for selecting the correct one:

$$F(s) = \int_0^\infty f(s)e^{-st}ds \quad F(s) = \int_0^\infty f(t)e^{-st}ds$$
$$F(s) = \int_0^\infty f(s)e^{-st}dt \quad F(s) = \int_0^\infty f(t)e^{-st}dt$$

which is a starting point for clarifying that, from a logical perspective, if we want to make time *disappear* from a given function $f(t)$, there is only one answer that makes sense. Later, it is mentioned that in practice the formula is almost never applied, since most Laplace transforms of interest are available in tables, which is an introduction to the next question.

***Question 3 - Order the Laplace transforms:*** $\delta(t) \Rightarrow 1(t) \Rightarrow e^{-3t}1(t) \Rightarrow \sin(3t)1(t)$ ***(60 s)***

In this *puzzle* question, the four possible answers:

$$1 \qquad 1/s$$
$$1/(s+3) \qquad 3/(s^2+9)$$

appear in a random order, and the players need to rearrange them in the correct order. The question provides the opportunity to remind the students what the Dirac delta and the unit step represent from a practical perspective, to mention that remembering that $\mathcal{L}\{1(t)\} = 1/s$ is particularly important since step signals are the most common type of reference in feedback control systems, and then to recall that:

$$\mathcal{L}\{e^{-at}1(t)\} = 1/(s+a)$$
$$\mathcal{L}\{\sin(\omega t)1(t)\} = \omega/(s^2+\omega^2)$$

***Question 4 - What is the Laplace transform of*** $f(t) = \left(10e^{-2t} + 15e^{3t}\right)1(t)$***? (60 s)***

In this *quiz* question, the students need to select the correct answer among different options:

$$F(s) = \frac{10}{s+2} + \frac{15}{s-3} \qquad F(s) = \frac{10}{s+2} + \frac{15}{s+3}$$
$$F(s) = \frac{10}{s-2} + \frac{15}{s+3} \qquad F(s) = \frac{10}{s-2} + \frac{15}{s-3}$$

This question serves the two purposes of (i) recalling *linearity* as one of the most important and useful properties of the Laplace transform; and (ii) highlighting that terms at the denominator looking like *s plus something* correspond to functions that converge asymptotically to zero in the time domain, whereas terms looking like *s minus something* "explode" to infinity in the time domain.

***Question 5 - What is the Laplace transform of*** $f(t) = [\sin(5t) + \cos(4t)]1(t)$***? (60 s)***

Here the students have to choose among the following options:

$$F(s) = \frac{5}{s^2-25} + \frac{s}{s^2-16} \qquad F(s) = \frac{5}{s^2+25} + \frac{s}{s^2+4}$$
$$F(s) = \frac{5}{s^2-5} + \frac{s}{s^2-4} \qquad F(s) = \frac{5}{s^2+25} + \frac{s}{s^2+16}$$

reinforces the idea that linearity is a very useful property, while at the same time recalling that $\mathcal{L}\{\cos(\omega t)1(t)\} = s/(s^2+\omega^2)$. The accompanying meme (see Fig. 2) clarifies the difference in spelling between *Laplace* and *Lapras*.

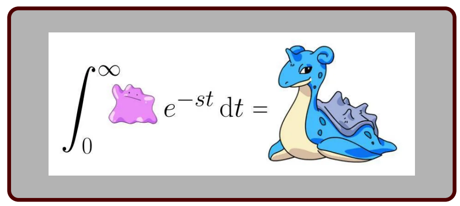


Fig. 2. Meme for Question 5, taken from the EEESAU Facebook page.

***Question 6 - The ******** ******** is the linear mapping of the*** $\mathcal{L}$***-transform of the input*** $U(s)$ ***to the*** $\mathcal{L}$***-transform of the output*** $Y(s)$***. (60 s)***

This is a *type answer* question that awards points for typing one among the following a priori correct answers: *transfer function*[3], *systemfunksjon*, *overføringsfunksjon*, *transfer-funksjon*, all of which appear automatically on the screen when the timer is over. In environments where the language of instruction differs from the country/region's official language or lingua franca, the extra correct answers can be used to inform the students about the translation of technical terms to another language (in this case, three possible Norwegian translations for the English *transfer function*). Note that it is possible to assign points *a posteriori*, after the answers submitted by the students appear on the screen, which is a way to account for typos (e.g., *Transfer functoin*) or other correct answers that the lecturer had not considered while preparing the question.

***Question 7 - The roots of the numerator*** $N(s)$ ***are called the ***** of Y(s). (30 s)***

***Question 8 - The poles of the denominator*** $D(s)$ ***are called the ***** of Y(s). (30 s)***

[3]The number and placement of * in the question provides a hint about this correct answer.

Both Questions 7 and 8 are of the *type answer* style, and their purpose is to recall terminology that is used widely during the course. In Question 7, accepted answers are *zeros*, *zeroes*, and their Norwegian translation *nullpunkter*, whereas in Question 8 accepted answers are *poles* and *poler*. After receiving the answers, the lecturer can proceed with further explanation, e.g. mentioning that for $Y(s) = \frac{(s+1)(s+2)}{(s+3)(s+4)}$ the zeros are $-1$ and $-2$ while the poles are $-3$ and $-4$, or providing some spoilers about future concepts in the course, e.g. mentioning that zeros of transfer functions are associated with blocking properties, possibly with some cross-disciplinary information that can connect to topics covered in other courses, e.g. the relevance of zeros for the design of notch filters in electronics.

### A. Divide an exercise (et impera)

The remaining of this section will show how a more complex exercise, which would be worded traditionally as follows:

*Given:*

$$Y(s) = \frac{(2\sqrt{3}+9)s^3 + (2\sqrt{3}-6)s^2 + (37-4\sqrt{3})s + 40}{s^4 + s^2 + 10s} \quad (1)$$

1) *Compute the corresponding* $y(t)$
2) *Apply the final value theorem to compute* $\lim_{t\to\infty} y(t)$

has been fragmented into simpler questions that guide the students along its solution. The above exercise is not appropriate for a single Kahoot question due to the amount of involved calculations, given that there exists an upper bound on the available time to answer a question (4 minutes) and because even a minor mistake could propagate into an incorrect submitted answer. Taking into account these reasons, several questions are used to guide the students towards its solution. For all questions, the *insert media* feature is used to provide the students with additional useful information. Some example of this are provided, although most are omitted due to space limitations.

***Question 9 - Given $Y(s)$, the first step to compute $y(t)$ is to... (30 s)***

In this *quiz* question, the players can select one among the following statements: (i) ...compute the zeros of $Y(s)$, (ii) ...compute the poles of $Y(s)$, (iii) ...compute the residues, and (iv) ...replace $\frac{d^n y(t)}{dt^n}$ wherever I encounter $s^n$. The *insert media* features is used to show the expression for $Y(s)$ in Eq. (1), which would otherwise exceed the length constraint enforced by the Kahoot platform, as a figure.

***Question 10 - Let's perform the partial fraction expansion/decomposition of $Y(s)$. We need to write... (60 s)***

In this *quiz* question, the players need to select the correct answer among different options:

$$Y(s) = \frac{r_1}{s} + \frac{r_2}{s+1+2j} + \frac{r_2^*}{s+1-2j} + \frac{r_3}{s-2}$$

$$Y(s) = \frac{r_1}{s} + \frac{r_2}{s-1+2j} + \frac{r_2^*}{s-1-2j} + \frac{r_3}{s-2}$$

$$Y(s) = \frac{r_1}{s} + \frac{r_2}{s+1+2j} + \frac{r_2^*}{s+1-2j} + \frac{r_3}{s+2}$$

$$Y(s) = \frac{r_1}{s} + \frac{r_2}{s-1+2j} + \frac{r_2^*}{s-1-2j} + \frac{r_3}{s+2}$$

Note that the players receive two different visual aids for this question. The first aid is the poles of $Y(s)$, given through the *insert media* feature (see Fig. 3), which also serves the purpose of refreshing the students' memory about the MATLAB command that computes the roots of a polynomial. The second aid is the presence of terms emphasized in the provided answers (using a red font), that highlight which parts of the expressions differ from one answer to another.

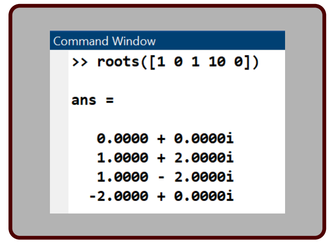



Fig. 3. Visual aid for Question 10.

***Question 11 - Then $r_1$ is computed as... (240 s)***
***Question 12 - ...$r_2$ is computed as... (120 s)***
***Question 13 - ...and finally we can compute $r_3$ which is equal to... (240 s)***

Questions 11-13 concern the computation of the residues in the partial fraction expansion. Question 11 is a *slider* question, where the players can select a number between -5 and 5 (with increments of 1). The picture (Fig. 4) provides all the information needed to calculate the correct answer. Note that a yellow background is used to highlight the currently considered parts of the exercise.

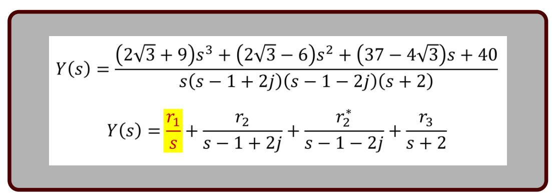



Fig. 4. Visual aid for Question 11.

After recalling how the generic $r_i$ is computed, and performing the calculations that lead to the correct answer $r_1 = 4$, the lecturer can proceed to Question 12 and get some additional insight into the players' level of understanding of the algorithmic procedure for performing the partial fraction expansion. Question 12 is a *quiz* question, with the players receiving the visual aid in Fig. 5, where the recently solved part of the exercise is highlighted using a green background.

They can select one among the following options:

$$r_2 = \left[\frac{(2\sqrt{3}+9)s^3 + (2\sqrt{3}-6)s^2 + (37-4\sqrt{3})s + 40}{s(s-1-2j)(s+2)}\right]_{s=1-2j}$$

$$r_2 = \left[\frac{(2\sqrt{3}+9)s^3 + (2\sqrt{3}-6)s^2 + (37-4\sqrt{3})s + 40}{s(s-1-2j)(s+2)}\right]_{s=1+2j}$$

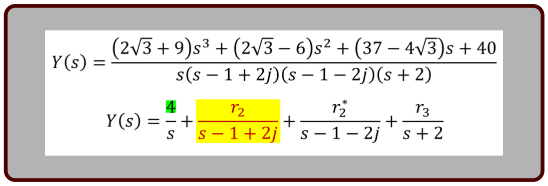



Fig. 5. Visual aid for Question 12.

$$r_2 = \left[ \frac{(2\sqrt{3}+9)s^3 + (2\sqrt{3}-6)s^2 + (37-4\sqrt{3})s + 40}{s(s-1+2j)(s+2)} \right]_{s=1-2j}$$

$$r_2 = \left[ \frac{(2\sqrt{3}+9)s^3 + (2\sqrt{3}-6)s^2 + (37-4\sqrt{3})s + 40}{s(s-1+2j)(s+2)} \right]_{s=1+2j}$$

Question 13 is another *slider* question, very similar to Question 11, and for this reason not further discussed. The visual aid for this question is provided in Fig. 6 for the reader's convenience.

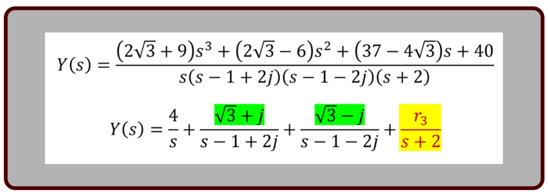



Fig. 6. Visual aid for Question 13.

***Question 14 - Now we can find $\rho_2$ and $\varphi_2$ so that $r_2 = \rho_2 e^{j\varphi_2}$. $\rho_2$ is given by... (120 s)***

***Question 15 - Now we can find $\rho_2$ and $\varphi_2$ so that $r_2 = \rho_2 e^{j\varphi_2}$. $\varphi_2$ is given by... (120 s)***

Question 14 and Question 15 are *slider* questions, meant to recall that complex residues should be converted into their polar form before proceeding with the inverse Laplace transform of $Y(s)$. Note that the visual aid (see Fig. 7) is used to highlight which part of the overall exercise the students should focus their the attention on.

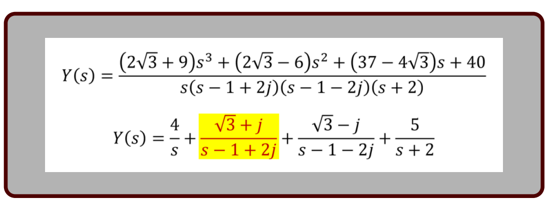



Fig. 7. Visual aid for Question 14.

***Question 16 - The inverse Laplace transform of $4/s$ is... (60 s)***

***Question 17 - The inverse Laplace transform of $\frac{2e^{j\frac{\pi}{6}}}{s-1+2j} + \frac{2e^{-j\frac{\pi}{6}}}{s-1-2j}$ is... (120 s)***

***Question 18 - The inverse Laplace transform of $5/(s+2)$ is *exp(***)1(t). Type: **** (120 s)***

Questions 16, 17, and 18 are about inverse transforming $Y(s)$ into $y(t)$, given the result of the partial fraction expansion. Question 16 is a *quiz* question where the students select one among the following options:

$$\begin{array}{cc} 4 \cdot 1(t) & e^{4t}1(t) \\ -4 \cdot 1(t) & e^{-4t}1(t) \end{array}$$

Question 17 is another *quiz* question with possible answers:

$$\begin{array}{cc} 4e^t \cos(2t - \frac{\pi}{6})1(t) & 2e^t \cos\left(2t + \frac{\pi}{6}\right) 1(t) \\ 2e^{j\frac{\pi}{6}t} \cos\left(3t + 2j\right) 1(t) & 4e^{j\frac{\pi}{6}t} \cos(3t + 2j)1(t) \end{array}$$

Finally, Question 18 is a *type answer* question, with a priori defined solution *5-2t*, although points can be assigned a posteriori for submitted answers that are technically correct, such as *5e^-2t*, *5exp(-2t)*, *5exp(-2t)1(t)* or *5exp-2t1(t)*. For each question, a visual aid is provided to keep track of the current status of the solution. For example, Fig. 8 shows that the term in $Y(s)$ of relevance while solving Question 17 is highlighted with a green background. At the same time, Fig. 8 shows the currently computed solution $y(t) = 4 \cdot 1(t) + \ldots$

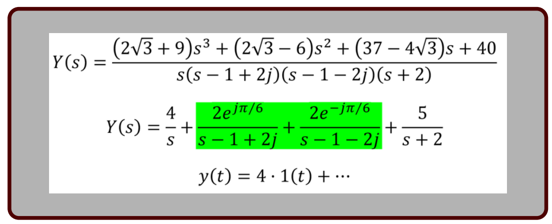



Fig. 8. Visual aid for Question 17.

After each question, a thorough explanation is provided, for instance after Question 17 the lecturer can recall the general formula for inverse transforming terms corresponding to complex conjugate poles:

$$\mathcal{L}^{-1}\left\{ \frac{\rho e^{j\varphi}}{s-\alpha-j\omega} + \frac{\rho e^{-j\varphi}}{s-\alpha+j\omega} \right\} = 2\rho e^{j\alpha t} \cos\left(\omega t + \varphi\right) 1(t)$$

Once completed the inverse Laplace transform of $Y(s)$, before proceeding to the last portion of the Kahoot, the final solution is portrayed using the embedded *slide* functionality, as shown in Fig. 9.

***Question 19 - By applying the final value theorem, we find out that $\lim_{t\to\infty} y(t) =$ ... (60 s)***

Question 19 is a *quiz* question with possible answers:

$$\begin{array}{cc} 0 & 2 \\ 4 & \text{Something else} \end{array}$$

The media feature is used to show both the specific $Y(s)$ under consideration and the statement of the final value theorem (see Fig. 10).

Notably, most of the submitted answer tend to be 0 or 4, either because the students do not realize that there is a simplification between the $s$ from the right-hand side of the formula and the $s$ at the denominator of $Y(s)$, or because they correctly calculate $\lim_{s\to 0} sY(s) = 4$. At this point, the lecturer proceeds to explaining that it is true that

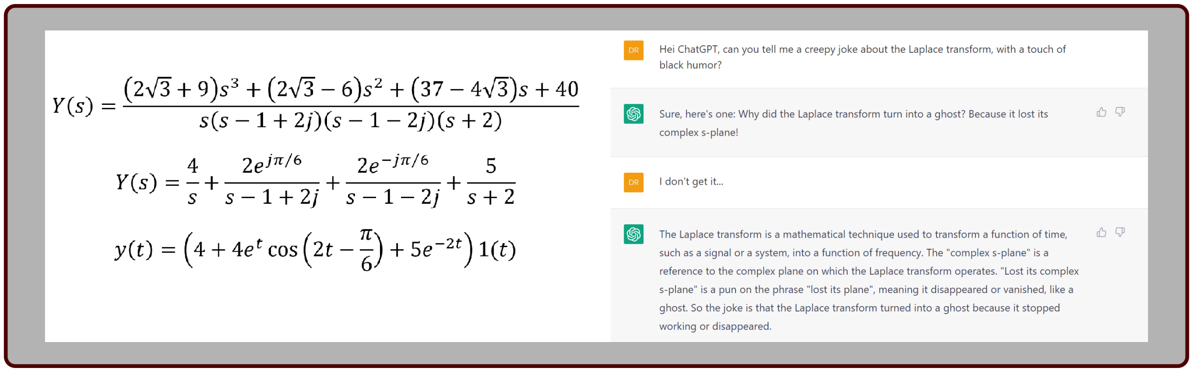



Fig. 9. Solution to the the first part of the exercise (with a touch of ChatGPT's humor [10])

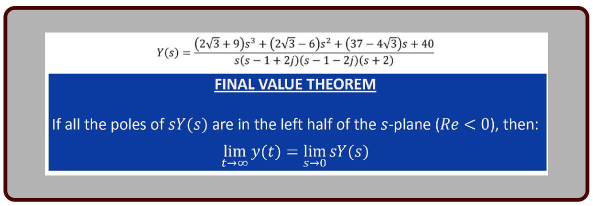



Fig. 10. Visual aid for Question 19.

$\lim_{s\to 0} sY(s) = 4$, but the correct answer is *something else*, thus proceeding to the final question of the lecture.

***Question 20 - Why? (60 s)***

This is a *word cloud* question, for which the visual aid is the angry face meme (see Fig. 11), used in situations where correct calculations lead to a wrong answer due to forgetting some important theoretical requirement or assumption (in this case, the *If* clause in the final value theorem). At this point, the students submit different answers ranging from vague (*because* or *tell me why*) to incorrect (*there is still a complex number in the denominator* or *because 8*5, 25*) to correct (*All poles must lie at the left side of the plane except one that van be 0. In this case there are poles alaonin the right aide of the s-plane* or *Positive poles*).

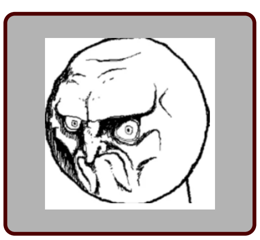


Fig. 11. Visual aid for Question 20.

## IV. Discussion

This section discusses the experiences with the use of Kahoot in control theoretical courses at the University of Stavanger. The basis for the discussion are:

- the quantitative and qualitative data collected by submitting a questionnaire to the students of the courses ELE620 and ELE320 in Autumn 2023/Spring 2024. A total of 27 responses were obtained (Table I provides the quantitative data, whereas Table II summarizes the perceived advantages and disadvantages of the use of the Kahoots in these courses, as perceived by the students)
- the lecturer's own reflections, partly based on the received comments in the final course evaluations of ELE320 and ELE620

It is not possible to please everyone, and this is true when using the Kahoot as well, as some students have mentioned in the final course evaluation that they perceive their time to be better spent with a more traditional approach to exercises and problems solving. However, most students perceive Kahoot as a very helpful and beneficial tool for their learning (7.4 average in the quantitative data). Notably, another question answered with a high score (7.9) concerns the impact of the memes on the learning experience. The use of humor in teaching is nowadays regarded as an active learning strategy that enhances learning by promoting comprehension and retention of information, while at the same time indirectly helping to trigger students' enthusiasm and interest in the subject [8]. Together with the higher interactivity brought by the Kahoot, with students participating actively to the lecture as proposers of ideas that spark further discussion (through the *open-ended* and some of the *type answer* questions) and problem solvers (through the remaining questions), humor contributes to lightening the mood in the lecture and boosting enjoyment. One of the most remarkable observed effects of this combination of humor and interactivity is that whereas the students would require a break midway through a traditional lecture, they would not mind going through a Kahoot-based lecture without any breaks. The Kahoot might also contribute to an increase in the attention span, which is consistent with the fact that the time limitation has been previously mentioned as a factor that gives students adrenaline in the learning activity [4].

With the aim of boosting the engagement of students, the introduction of prizes (giftcards for the faculty café) has been implemented. The awarding criteria have been a topic of experimentation, with the current implementation consisting

TABLE I

QUANTITATIVE DATA FROM QUESTIONNAIRE

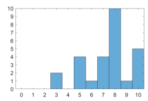
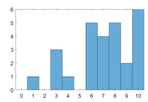
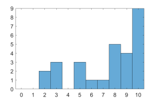
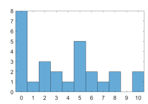
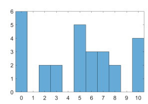
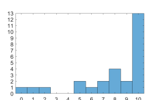
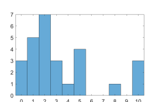
| Question | Histogram | Mean | STD |
|---|---|---|---|
| How different are the Kahoots in my course(s) compared to those you have experienced in other courses? |  | 7.4 | 2.0 |
| How much do you feel that the Kahoots in my course(s) help you to clarify/understand important concepts in the subject? |  | 7.0 | 2.5 |
| How much do you feel that the Kahoots are beneficial for your learning process? |  | 7.4 | 2.8 |
| How much does the presence of prizes motivate you while playing the Kahoot? |  | 3.6 | 3.2 |
| How much does the presence of the lottery keep you motivated until the end? |  | 4.8 | 3.4 |
| How much does the presence of memes have a positive impact on your learning experience? |  | 7.9 | 3.0 |
| How much would you prefer that the time spent for the Kahoots were used to solve exercises on the blackboard instead? |  | 3.3 | 3.0 |

TABLE II

QUALITATIVE DATA FROM QUESTIONNAIRE

| **Advantages of Kahoot'ified lectures** |
|---|
| Combined with explanations on the board give better understanding and intuition; one gets assignments does faster as has already started to exercise by oneself; gives a good idea of what type of questions might come up on the exam; fun way to revisit core concepts and gain academic bragging rights over fellow students; it's a really fun way to learn; useful to keep one interested during the last class of the week. |
| **Disadvantages of Kahoot'ified lectures** |
| Sometimes too much time is used for explaining the answers; there are some students who use Kahoot cheating tools, making it unfair to other students; some tasks have confusing/complicated answering methods due to technical limitations in Kahoot; it doesn't work well for those who cannot do math so well within a relatively short amount of time. |

of one prize awarded to the winner of the Kahoot plus another prize awarded to one among the remaining students through a lottery, where tickets are earned by the students for reaching specific point thresholds. Although the presence of prizes is not a strong extrinsic motivator per se (score of 3.6), the presence of the lottery contributes to motivate some students until the very end (4.8), as even students who fell behind their classmates still have the change to receive a prize by answering to the remaining questions correctly. Note that the questions related to the prizes are the ones with the most standard deviation, which can be interpreted as: some students do not need or do not mind the extra motivation brought by the prize, but some other students do.

On the whole, the students have positive opinions about Kahoot and its usefulness for their learning process, and they would rather prefer to have additional opportunities to use them (available offline during the course after they have been used in a live lecture, or assigned after obligatory tasks) than to solve exercises in a more traditional way (3.3).

## V. CONCLUSIONS

This paper has shown how the premium features of Kahoot can be exploited to design a Kahoot-centered lecture that engages students in active participation. The data collected through a questionnaire point out towards the students' positive appreciation of the use of Kahoot in control theoretical courses. An open issue that deserves further investigation is how to time the Kahoots for achieving the best possible learning efficiency.

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