# Interdisciplinary learning of electronic circuits: faculty members' perspective

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ABSTRACT: Recently, the Faculty of Electrical and Computer Engineering at the Technion - Israel Institute of Technology, Haifa, Israel, developed an interdisciplinary course on electronic circuits. This undergraduate-level course combines the analogue and digital viewpoints that are traditionally taught separately in higher education. The present study aimed to characterise faculty members' attitudes towards interdisciplinary learning of electronic circuits, whether they are based on experience or on belief. As part of the research, 11 in-depth interviews were held with faculty members who have taught electronic circuits at three leading Israeli universities. According to the findings, instructors who have experienced interdisciplinary teaching argue that interdisciplinarity promotes understanding, improves students' training in general and their ability to see the overall picture in particular, but is also characterised by a heavy cognitive load and a tendency to superficiality. Instructors who have experienced disciplinary teaching think that interdisciplinarity provides a comprehensive view, places a high load and tends to be superficial. However, they also believe that it is unnatural and impairs understanding. The article offers a possible explanation for these partially contradictory positions.

Keywords: Interdisciplinary learning, faculty members' attitudes, electronic circuits

## INTRODUCTION

Interdisciplinary learning, namely, learning that integrates two or more fields of knowledge, has many advantages [1]. Thus, for example, it often promotes understanding [2] and higher-order thinking skills, such as analysis [3]. Therefore, the Faculty of Electrical and Computer Engineering at the Technion - Israel Institute of Technology, Haifa, Israel, decided to develop an undergraduate-level course on electronic circuits that combines the two main branches of electronics, i.e. analogue electronics and digital electronics. These areas are based on different assumptions, use different models and have different purposes. However, since they share the same physical devices, many parameters are interrelated. The interdisciplinary approach mentioned above replaced, at the Technion, the traditional disciplinary way, prevalent in academia that separates the two branches of electronics [4].

The research described here characterised, using in-depth interviews, faculty members' attitudes towards interdisciplinary learning of electronic circuits, whether they are based on experience or on belief. To the best of the authors' knowledge, such analysis was performed here for the first time. The research findings expand the body of knowledge on the subject and may improve the training of engineers. These contributions are further validated in light of the notable gap between the skills of engineering graduates and those required in the industry [5].

The article opens with a concise theoretical background that reviews relevant aspects of interdisciplinary learning. Next, the interdisciplinary course Electronic Circuits developed at the Technion is described. Then, the research goal and methodology are presented. Finally, the main findings are discussed.

## INTERDISCIPLINARY LEARNING

As mentioned, interdisciplinary learning combines two or more areas of knowledge [6]. In this way, it differs from disciplinary learning that focuses on a single field and from multidisciplinary learning, in which the student deals with several areas but treats each of them separately (Figure 1) [7].

The literature also distinguishes between narrow interdisciplinarity, where the fields of knowledge are close, i.e. use similar epistemologies and methodologies, and wide interdisciplinarity, where the disciplines involved are far from each other [8].

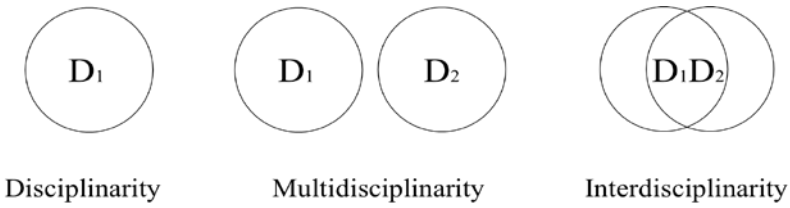


Figure 1: Disciplinarity, multidisciplinarity and interdisciplinarity.

Interdisciplinary learning enables a holistic observation of a given subject [3]. Therefore, there are considerable benefits inherent in it, both in the cognitive domain, e.g. promoting understanding and analytical skills [9], and in the affective realm, e.g. fostering intrinsic motivation [10]. Thus, over the years, interdisciplinary programmes have been developed on various topics [11][12] and for different audiences [13][14].

Along with these advantages, interdisciplinary learning may be perceived by students as accompanied by a heavy load. This load stems from the need to cover, in a relatively short time, a large number of concepts that are essential for comprehending the relevant disciplines and the need to understand their interrelations [15]. In addition, interdisciplinary learning may be perceived as superficial, due to the above and/or an imbalance between the disciplinary and interdisciplinary components [16].

## ELECTRONICS CIRCUITS COURSE

The Electronic Circuits course is a narrow interdisciplinary course aims to provide the student with circuit analysis skills from both the analogue and digital perspectives. Therefore, it underscores the interrelations between these two viewpoints. The course consists of disciplinary components, digital electronics and analogue electronics, as well as interdisciplinary components (Table 1).

Table 1: Electronic Circuits course - selected topics.

| Disciplinary components | | Interdisciplinary components (three weeks) |
|---|---|---|
| Digital electronics (four weeks) | Analogue electronics (six weeks) | |
| Logic circuits, noise margins, transition times and delays, static and dynamic power, speed optimisation and logical effort, timing requirements, regeneration, synchronisation, latch registers, sequential circuits, meta-stability | Gain stages, large *versus* small signal, linearisation, equivalent circuits, frequency response, differential amplifier, feedback and stability | Analogue to digital and digital to analogue conversion, noise analysis |

The course is mandatory for junior electrical and computer engineering students, lasts 13 weeks and is comprised of four hours of lectures and two hours of tutorials per week. In these sessions, the teaching method is front-facing. The assessment is based on homework and a final examination.

## RESEARCH GOAL AND METHODOLOGY

The study aimed to characterise faculty members' attitudes towards interdisciplinary learning of electronic circuits, whether they are based on experience or on belief.

Eleven faculty members involved in the teaching of electronic circuits took part in the study. Five of them have taught the interdisciplinary course Electronic Circuits at the Technion. The rest have taught electronic circuits in the disciplinary approach; namely, separate courses in analogue electronics and in digital electronics, at the Technion, Tel Aviv University and Ben-Gurion University of the Negev, Israel. All faculty members have advanced degrees in electrical and computer engineering and substantial teaching experience.

The participants were interviewed (semi-structured interviews). The interviews were recorded and transcribed in full. The qualitative data were categorised through directed content analysis [17] performed by two engineering education experts. The analysis was based on the characteristics of interdisciplinary learning, described above. A sample of the interview questions is given in the Appendix.

## FINDINGS

First, the attitudes of faculty members who have experienced interdisciplinary teaching are described. Then, the attitudes of their peers who have experienced disciplinary teaching are presented.

Attitudes of Faculty Members Who Have Experienced Interdisciplinary Teaching

Eighty percent of the instructors claim that interdisciplinary learning of electronic circuits makes it possible to see the overall picture: …*You* [student] *benefit when you understand both perspectives* [analogue and digital] *of the same circuit.* In addition, 80% of them think that interdisciplinary learning improves professional training: …*I think this course* [electronic circuits] *will give a huge advantage to its graduates in their work in the industry*. Forty percent of the teachers argue that the holistic view characterising interdisciplinary learning improves understanding: …*Separate courses* [in analogue electronics and digital electronics] *emphasise algebra and tricks... this* [holistic] *course emphasises understanding*.

At the same time, all teachers are aware of the high cognitive load that accompanies interdisciplinary learning: …*We* [course faculty] *try to cram a lot of content into a short space of time.* And 40% of them claim that the ability to delve into the material is low: …*There is a distinct advantage to studying* [analogue electronics] *separately* [from digital electronics]*... there is more time to study and deepen.*

Attitudes of Faculty Members Who Have Experienced Disciplinary Teaching

Half of the instructors who have not experienced interdisciplinary teaching believe that interdisciplinary learning of electronic circuits allows one to see the overall picture: …*Interdisciplinary learning provides a comprehensive view of the essence of electronics.*

At the same time, 83% of the teachers think that interdisciplinary learning is superficial because it does not permit to delve into the material as required: …*The point is that it* [interdisciplinarity] *comes at the expense of the other* [depth]. Two-thirds of them believe that interdisciplinary learning may induce a high cognitive load: …*You* [teacher] *have to cover large-signal analysis* [digital electronics]*, small-signal analysis* [analogue electronics] *... and many, many more* [topics], and that it may impair understanding: …*The advantage of holism cannot justify the decreased understanding of how circuits are analysed.*

Moreover, according to a third of the teachers, the fundamental differences between analogue electronics and digital electronics make interdisciplinary learning unnatural: …*The differences* [between analogue electronics and digital electronics] *are significant... I do not understand why to combine the two.*

DISCUSSION AND CONCLUSIONS

Comparing the attitudes of faculty members who have experienced interdisciplinary teaching of electronic circuits to those of their peers who have experienced disciplinary teaching shows that both groups think that interdisciplinary learning allows one to see the overall picture, but is also characterised by a high cognitive load and a tendency to superficiality. As noted, these features are often mentioned in the research literature [15][16].

Along with this agreement, the two groups differ in their opinions. Faculty members who have experienced interdisciplinary teaching identify considerable advantages in interdisciplinary learning of electronic circuits, such as improved understanding (due to the holistic view) and improved professional training. In contrast, faculty members who have experienced disciplinary teaching believe that interdisciplinary learning of electronic circuits is unnatural (due to the fundamental differences between the areas) and may impair understanding.

Similar findings were reported in Gero's study, showing, in the case of pre-service teachers that lack of experience in interdisciplinary teaching leads to non-positive (negative or neutral) attitudes towards it, while some experience in interdisciplinary teaching leads to positive attitudes [18]. This may be due to an initial reluctance to teach in an interdisciplinary approach, which is considerably different from the traditional disciplinary way [19].

It is interesting to compare the attitudes of faculty members who have taught electronic circuits to those of students. Students who have experienced interdisciplinary learning of electronic circuits and their peers who have experienced disciplinary learning think that interdisciplinarity imposes a high cognitive load and tends to be superficial.

However, while the former claim that interdisciplinarity constitutes a natural approach to electronic circuit analysis (because the analogue and digital perspectives are interrelated) and promotes understanding and professional training, the latter believe that it is unnatural (due to the fundamental differences between the fields) and, thus, may harm understanding [4]. That is, even in the case of students, the very experience of interdisciplinarity led to somewhat positive attitudes towards it. It turns out that there is a great similarity between the attitudes of faculty members and those of students, as shown in Table 2.

In practice, the analytical skills of students who studied electronic circuits in the interdisciplinary approach were significantly higher than those of their peers who studied in the disciplinary way [4]. This result is consistent with the literature indicating that interdisciplinarity often develops higher-order thinking skills [3].

The findings of the present study and those described by Catz et al [4] point to the importance of exposing faculty members and students to interdisciplinary education. Such exposure may impart positive attitudes towards interdisciplinarity.

Table 2: Interdisciplinary learning of electronic circuits - attitudes of faculty members and students.

| | Faculty members | | Students [4] | |
|---|---|---|---|---|
| | Experience in interdisciplinary teaching | Experience in disciplinary teaching | Experience in interdisciplinary learning | Experience in disciplinary learning |
| Strengths | Provides a comprehensive view | | | |
| | Advances understanding<br>Promotes professional training | | Natural<br>Advances understanding<br>Promotes professional training | |
| Weaknesses | Places a high cognitive load<br>Tends to be superficial | | | |
| | | Unnatural<br>Impairs understanding | | Unnatural<br>Impairs understanding |

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BIOGRAPHIES

Beto Catz holds a BSc in electrical engineering, a BSc in technology and science education (*summa cum laude*) and an MSc in technology and science education (*cum laude*), all from the Technion - Israel Institute of Technology, Haifa, Israel. In addition, he has an MBA (*cum laude*) from the University of Derby, UK. Mr Catz has many years of experience in electronics design, and has served in technological and management positions in leading companies. He is an adjunct lecturer in the Department of Electrical and Electronic Engineering at Braude College of Engineering, Israel, and serves as the coordinator for interdisciplinary and entrepreneurship academic programmes at the College's Engineering Education and Entrepreneurship Centre. Currently, Mr Catz is a PhD student in the Department of Education in Technology and Science at the Technion.

Aharon Gero holds a BA in physics (*summa cum laude*), a BSc in electrical engineering (*cum laude*), an MSc in electrical engineering, and a PhD in theoretical physics, all from the Technion - Israel Institute of Technology, Haifa, Israel. In addition, he has an MBA (*cum laude*) from the University of Haifa, Israel. Dr Gero is an Assistant Professor in the Department of Education in Technology and Science at the Technion, where he heads the Electrical Engineering Education Research Group. Before joining the Technion, he was an instructor at the Israeli Air-Force Flight Academy. Dr Gero's research focuses on electrical engineering education and interdisciplinary education that combines physics with electronics, at both the high school and higher education levels. Dr Gero has received the Israeli Air-Force Flight Academy Award for Outstanding Instructor twice and the Technion's Award for Excellence in Teaching 16 times. He received the Israeli Air-Force Commander's Award for Excellence (2006), the Yanai Prize for Excellence in Academic Education (2016) and the Technion's Award for Continuing Excellence in Teaching (2022). Dr Gero is an Associate Editor of IEEE Transactions on Education.

APPENDIX

Below is a sample of the interview questions:

- What, in your opinion, are the strengths of studying electronic circuits in two separate courses; namely, a course on analogue electronics and a course on digital electronics?
- What, in your opinion, are the weaknesses of studying electronic circuits in two separate courses; namely, a course on analogue electronics and a course on digital electronics?
- What, in your opinion, are the strengths of studying electronic circuits in a single course combining analogue electronics and digital electronics?
- What, in your opinion, are the weaknesses of studying electronic circuits in a single course combining analogue electronics and digital electronics?