EVALUATING A DIGITAL SIGNAL PROCESSING COURSE IN AI ERA

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ABSTRACT

A methodology for evaluating a Digital Signal Processing course in the modern Artificial Intelligence era is presented. The course is part of the Bachelor's program in Artificial Intelligence at the Federal University of Goiás, Brazil. The evaluation process contemplated a design-implement experience based on the CDIO framework for a course module whose contents evolve quickly due to a fast moving AI industry. The evaluation process was designed in cooperation with the Center of Excellence in Artificial Intelligence in Brazil. The course contents consisted of regular lectures for eleven weeks on signal processing topics, such as signal analysis, spectral analysis and synthesis and image processing. The last five weeks were dedicated to the development of a project involving state-of-the-art Artificial Intelligence methods. The learning tools provided to the students included a classroom platform to upload and share materials and a version control system to keep track of project deliverables, such as slides, project documentation and a kanban to measure teamwork. Forty-four students participated in the learning activity. Two surveys were applied to the students at the course completion in order to assess the level of achievement of the learning outcomes. As a result, the students were able to successfully conduct a project-based learning experience addressing challenging AI applications that expanded the limits of the traditional course contents in a systematic way. We designed a learning environment that allowed us to assess hard and soft skills during the learning process, which are abilities demanded by modern industries. Finally, reflections and observations and student feedback were collected to further improve the course module in further iterations.

KEYWORDS

Digital signal processing, artificial intelligence, evaluation, Design-implement experience, project-based learning, Standards: 2, 4, 5, 11.

INTRODUCTION

The availability of generative artificial intelligence resources, as educational tools, brings new challenges and opportunities to the academic community. Students now have access to powerful software able to exploit the heterogeneous online information on the internet contained in the form of text, video, audio or images, in a simple and fast way. Modern artificial intelligence (AI) systems can answer complex questions and explain the rationale behind them step by step using natural language, as if it was a conversation with an expert in the field. However, the correct use of AI requires a criterious screening of the answers in order to avoid misleading information called *hallucination* (Athaluri *et al.*, 2023). The adoption of AI tools by educators requires two key elements: adapting the course structure to support this new learning resource and the ability to cope with the rapid evolution of technological content (Holmes & Tuomi, 2022).

This work describes the process of evaluating a Digital Signal Processing course in the artificial intelligence era, a context characterized by high availability of online information and rapidly evolving subjects. A main aspect of this contribution was the switch from a traditional learning approach based on lists of exercises to project-based learning implemented as a design-build experience (see Standard 5) (Boughattas, Neji, Zladi, 2024)). An important strategy was focusing on developing the student's individual skills by allowing them to address challenging topics of their interest with the use of AI. We strongly believe that embracing AI as part of the educational process can help to design more customized and personalized learning environments. As a contribution to the CDIO community, we propose an evaluation process that can accommodate fast-paced topics in technology-aided curricula, such as Digital Signal Processing and related subjects.

We can discuss data sources as an example of customization of the learning process. Traditional course contents on signal processing, for instance, typically involve working with time series, signals, or images. Due to high availability of open data sources, datasets, code and online documentation, we were able to expand the course contents to more complex data types, such as text, audio, speech and video analysis. This, of course, implied expanding the horizon of processing techniques to deal with such signals, for example, including large language models (LLMs) for natural language processing; generative AI models (genAI) for image generation; visual transformers and deep neural networks to work with style transfer in images, or; neural data compression for fast information retrieval. The role of the instructor also changes from a traditional server of information to a "*facilitator"* that promotes learning environments that allow scientific discoveries in a controlled playground.

A key challenge still remains: How to address and evaluate rapidly evolving subjects? A possible direction towards the answer is to keep our work updated with standardized methods and professional practices. The current is a follow-up on previous authors' work, in which we improve on top of related design-build experiences (Gunnarsson & Díaz-Salazar, 2023; Díaz-Salazar *et al.*, 2025). We discuss our strategy for incorporating constantly changing contents in traditional course structures in the following sections.

EVALUATION THROUGH PROJECT-BASED LEARNING

We propose a design-build experience based on team management and project-based learning. The instructor's role is assumed by the lecturer, who is responsible for validating the student's projects. During the first eleven weeks, the students received lectures on the fundamentals of the subject, such as signal and spectral analysis, time-frequency analysis, and image processing. In the last five weeks, the students proposed a project to be worked in groups with focus on exploring artificial intelligence methods.

AI methods were presented in an introductory manner during the first weeks of the course. However, the students opted for more advanced methods since they were early exposed to practical projects conducted at the Center of Excellence in Artificial Intelligence (CEIA) during the first years of the program. The class instructor suggests the main topics of exploration, while the groups define the specific themes and validate them with the instructor. The instructor impulses the students' decision for them to benefit from the high availability of online resources, such as blogs, tutorials, and videos (*e.g.*, medium, youtube), and the access to public repositories of data and code (*e.g.,* kaggle, hugging face, github, papers with code). In such a sense, the students are free to propose the topic of their work, which becomes a potential candidate according to the description of the scope and goals.

The CDIO framework in the AI era

While the idea of integrating generative artificial intelligence into higher education offers exciting possibilities for personalized learning, training undergraduate students with the competencies required by a rapidly evolving industry is a significant challenge. One of the primary hurdles is the sheer speed of innovation. Traditional curricula often struggle to keep pace with the high availability of online resources and the constantly changing nature of technology-based education (Holmes & Tuomi, 2022). Integrating a professional-grade AI curriculum demands more than just theoretical knowledge, it requires an educational structure that can adapt as quickly as the technology itself. Without a framework that bridges the gap between theory and practice, educators face critical questions: How do we teach effectively in the age of LLMs? How do we evaluate learning outcomes when students have access to powerful generative tools?

To address these challenges, this work proposes a CDIO design-build experience that embraces AI as a core educational resource. Instructors are challenged to shift their role as providers of information to facilitators that promote learning environments with advanced and up-to-date topics (CDIO, 2026). Students' workload moves beyond theoretical exercises to more practical developments involving state-of-the-art methods and protocols. The ultimate goal is to train students who are not only technically competent, but also critical thinkers capable of managing complex AI projects safely and ethically (Mezilov *et al*., 2024).

THE CONTEXT OF THE DESIGN-IMPLEMENT EXPERIENCE

The Bachelor's Program in Artificial Intelligence

The evaluation of the course module focused on the development of software products aligned to the core program, such as deep learning, computer vision and natural language processing. The BIA is a four-year program composed of eight semesters corresponding to 3,200 hours in total. The first three years correspond to courses in Entrepreneurship, Mathematics, Computer Science, Machine Learning, and Deep Learning. The Digital Signal Processing module is given in the fourth semester, with a total of 64 hours of credits. It is the third course where students are introduced to a design-implement experience, according to the CDIO framework (other CDIO courses on the program are Computer Vision, at the fifth semester, and Robotics, at the seventh semester). The fourth year of the program includes modules on Natural Language Processing, Reinforcement Learning, Robotics and Big Data. The program concludes with a Residence Program in Artificial Intelligence in the eighth semester, in which students work 320 hours of credits on a capstone project, as part of the requirements for graduation.

Structure of the DSP course module and learning goals

The module on Digital Signal Processing is 16-week long, which is equivalent to 3 ECTS credits (a year of full-time studies corresponds to 60 ECTS credits). The students are expected to spend 64 hours on the subject. The learning outcomes are:

- (Unsupervised) Explain the different phases of digital signal and image processing.
- (Supervised) Apply the basic algorithms of signal and image processing.
- (Following instructions) Model and implement sets of algorithms for the different phases of signal and image processing.

There are three levels of independence students must accomplish towards reaching a learning outcome. The levels of independence were designed as checkpoints for instructors to evaluate the learning process incrementally. “Unsupervised” means the students are expected to accomplish entry level goals without support from the instructor. This level was assessed through oral interventions. “Supervised” means the students act independently on intermediate level tasks, but are allowed to receive support. This was evaluated through practical laboratories. On “Following instructions”, the students are expected to execute more advanced activities. This level was assessed through a seminar implemented as a group project. In our case, the seminar was the only activity to receive a grade, while the oral tests and laboratories served to prepare the class with basic technical content.

The first eleven weeks of the module were used to present signal processing topics, such as signal and frequency analysis, spectro-temporal analysis, and image processing. The last five weeks were dedicated to the development of a group project presented as a seminar. In the following sections we explain the details of assessing the seminar process.

Evaluating software-based projects

Forty-four students took part in the course module. The evaluation consisted of preparing a capstone project for five weeks. The students were self-organized in groups of four members. From week one to eleven, the class received inductions during lectures to stimulate the proposal of projects involving modern AI applications. The topics were suggested by the instructor and refined by the students iteratively. This allowed us to expand the curriculum beyond the topics that can be explored in a period of sixteen weeks and to promote scientific discovery by working on personal projects. The learning environment simulated an immersive work experience where the participants developed a project judged by a sponsor (the instructor).

The evaluation process was performed in the following sequence:

- **Project proposal and Validation (Week 11):** In Weeks 6 and 7, the students search for project topics individually. In Weeks 8 and 9, they should identify candidate members to form teams of four people. They received a project template to be fulfilled as project documentation. In Week 11, the teams submit an abstract of the proposal to be discussed and validated with the instructor. The validation process consisted of verifying the goal and scope of the work. To validate the goal, it was checked the object of study (time series, images, text, or tabular data). To validate the scope, the proposal should fit five weeks of work. If the scope was too short, the team was asked to include additional tasks as goals. If it was too long, the team should divide the proposal in stages to be delivered incrementally.

- **First checkpoint (Week 14):** The first checkpoint consisted of an oral examination in the form of a five-minute pitch. The deliveries were the presentation slides, a kanban of the work in progress, and a partial project documentation. The teams received feedback focused on improving soft skills (presentation) and hard skills (project management). Soft skills were improved with hints for catching up the audience's attention, keeping good posture, controlling time and speaking out loud. Hard skills were improved with hints on using up to date datasets, suitable research methods, or specialized literature.
- **Second checkpoint (Week 16):** The final checkpoint consisted of an oral examination of eight minutes with additional two minutes for practical demonstrations. The deliveries were the presentation slides, a completed kanban, and the final project documentation.

In order to successfully assess the seminar, we used a couple of online learning resources:

- **Learning platform:** We adopted Google Classroom as the classroom environment because it allowed us to communicate effectively with the class by sharing slides, practical exercises, videos, and information about the conduction of the seminar projects. The platform comes with a mobile version that is also useful for sharing instant updates and news.
- **Project deliverables:** The deliverables were submitted through GitHub in order to organize them on individual team repositories containing the slides, code, project documentation, and kanban for teamwork assessment. As version control systems, Git-based platforms also allow evaluating incremental work in progress on each submission, if required.

Teamwork was one of the hardest aspects to evaluate. A step forward towards addressing it was to require a kanban for weekly task definition. A kanban is a simple and effective way for instructors to monitor the progress of teams at a high-level of granularity. It also allows instructors to detect negative practices, such as micro management, without interfering too much into the process. Kanban is also a standard tool for project management in modern agile frameworks of software development.

Examples of project tasks and results

Twelve projects were validated in total with the following proposals:

1. Diffusion transformers for generation of manga artwork.
2. A data communication protocol through acoustic waves via 256-FSK modulation.
3. Denoising and detrending of ECG signals using AI methods to support physicians in diagnosing cardiac anomalies.
4. Reconstruction of 3D objects from multiple images using Gaussian splatting and NeRFs.
5. Comparison of Discrete Cosine Transform and autoencoders for image compression and applications in Content-Based Image Retrieval.
6. Manual feature extraction versus trained neural network embeddings for the classification of musical audio signals and Music Information Retrieval applications.
7. Extraction of embeddings with Reinforcement Learning for DeepFake analysis.
8. Spectral analysis and filter design for the detection of Bitcoin halving cycles.
9. Analysis of wildfires using deep learning segmentation in videos.

10. Super-resolution in images and videos using generative adversarial networks.
11. Automatic translator of Brazilian regionalisms.
12. Style transfer in images using diffusion models.

A common characteristic of the proposals is the complexity of the topics. Students in the AI era have access to rich online resources, such as blogs, tutorials, datasets, articles with documented code and examples, that facilitates exploring such sophisticated subjects. To keep the students confident with them, failure needed to be embraced as part of the learning process during checkpoints. An oral screening was taken during the validation of proposals in which students agreed on achieving the learning outcomes regardless of project results being positive or negative. Recognizing mistakes as a constructive outcome helps to mitigate the fear of failure.

Some of the teams used online available data, so the workload was on studying complex signals (*e.g.*, Projects 1, 3, 4, 5, 7, 8, 9, 12). Whenever data collection was necessary (*e.g.*, Projects 2, 6, 10, 11), the feasibility of the project was double checked with the students during validation to verify that the team would be able to collect the required data timely to meet the deadlines.

Two examples of the validation phase are Projects 5 and 11. The Project 5 team proposed studying image compression using a classical spectral analysis approach. As the goal was short for the proposed schedule, the project scope was extended to incorporate deep learning methods for image compression, such as embedding generation with autoencoders, in order to fulfill the five-week requirement. The proposed new methods were all well documented in literature, so the team would be able to compare classical methods with more modern ones within the timeframe. On the other hand, the Project 11 team proposed studying style transfer on voice signals using established methods and data. In such a case, the suggestion for the team was to adapt the experiment in order to build a dataset that allows translating phrases originated from a Brazilian regional dialect to a different one. The team validated the scope properly by identifying and documenting the steps required to address the new problem. Although the final result was simplified to the translation of words rather than phrases, the team managed to execute the proposed methodology to analyze such complex signals and demonstrated that phrase analysis could be performed with a larger time budget.

A survey was applied to the class by the end of the course. The questions were designed in cooperation with two students in order to collect the class' opinion about the learning experience. The survey measured the level of achievement of the three learning outcomes at the completion of the course module. It also ranked the lectures and the evaluation method, and contemplated space for general comments and suggestions.

Eleven students (N = 11) answered the survey in total, with the following results:

- I am aware that the responses to the form are <u>ANONYMOUS</u>? Yes (100%), No (0.0%).
- Can I explain the different phases of digital signal and image processing? Yes (45.5%), Partially (54.5%), No (0.0%).
- Can I explain the basic algorithms for signal and image processing? Yes (45.5%), Partially (45.5%), No (9.1%).
- Can I model and implement sets of algorithms for the different phases of signal and image processing? Yes (81.8%), Partially (18.2%), No (0.0%).
- Rate the DSP lectures from 1 to 5: 1 (0.0%), 2 (0.0%), 3 (27.3%), 4 (45.5%), 5 (27.3%).
- Rate the evaluation method used on a scale of 1 to 5: 1 (0.0%), 2 (0.0%), 3 (9.1%), 4 (27.3%), 5 (63.6%).

- Please provide suggestions below for changes to the lectures and/or assessment method:

  Student 1: *“I believe the evaluation was very well done. Regarding the classes, I felt they covered topics without explaining how to do them from the beginning, leaving the student to figure it out on their own. But how can you do something you've never seen anyone do before? Sometimes the challenges are too great for some students, and this can make them feel the content is too difficult. However, perhaps this could be resolved by showing how to do it the first time.”*

  Student 2: *“I think the classes were very expository, but they lacked more encouragement of practice. More than what was done in class; objective exercises on the topics covered would be a good way to do this, in my opinion.”*

  Student 3: *“I think the idea of the classes being more practical was very good, to present the content and give us a "challenge" on how to solve/implement what we saw in theory but now in practice. I only missed more "concrete" feedback on the solutions and the steps taken to arrive at them. I say this because the solutions were presented in class and the step-by-step process was followed, but if people weren't paying 100% attention and missed a step, they could get lost in the rest of the stages, and it would be difficult to recover that later because there was no material with the "answer." (...). But overall, that was it. I really liked how the subject was conducted, and the two-week evaluation method (which ended up being three by chance) was also very good because we had that initial week to do the first tests and see where we were going, and then we had more time to work on a final project. So, two weeks of evaluations was very good for that reason. In my view, if we had another week of "intermediate" progress, it could have ended up being too redundant and similar to the final results, and it wouldn't have been as interesting as it turned out to be. Otherwise, congratulations, I really enjoyed the material!”*

  Student 4: *“The classes could be more dynamic and have more weekly practical activities.”*

The university also applied a mandatory survey by the end of the semester, whose results are shown in Table 1 (SIGAA, 2026).

Table 1. Results of the evaluation of the teaching process by the class

N	Suspensions	Dimension 2		Dimension 3		Total Avg. [1]	Total Std. [1]
		Avg.	Std.	Avg.	Std.		
41	0	9.19	1.88	9.46	1.10	9.19	1.66

[1] Total Average and Total Standard Deviation are calculated from Dimension 1 - “Evaluation of the Institution by the Student” and Dimension 2 - “Evaluation of the Instructor by the Student”, which are metrics defined by UFG, of a maximum of 10.0 points. Dimension 3 - “Self-assessment by the student” follows a similar standard.

Observations and student feedback

Some lessons learned can be summarized by the end of the learning activity:

- The question, "how do we evaluate learning outcomes when students have access to powerful generative tools?", could be partially addressed. The focus on project-based learning allowed us to achieve the learning outcomes in a bottom-up approach, starting by the “Following instructions” level on project definition and validation, followed by the “Supervised” level on the development of weekly tasks, and concluding with the “Unsupervised” level at oral presentations.
- Potential factors that could limit the model’s implementation are the scalability to larger cohorts, the ability and experience of the instructor to guide the teams through managerial details, and the subjective effectiveness of the proposed software tool (git) for teamwork assessment.
- The students reported a high level of satisfaction. This was achieved by helping the teams to choose their seminar topics rather than imposing them, and to provide constructive weekly feedback that helped teams to accomplish their goals. Although this might seem unfair to the evaluation, we must remember that learning is essentially an individual process and that the transformation of mindset becomes evident over time. The focus of our approach is on providing a learning environment with proper educational resources to enable students to develop their own ideas.
- We identified a trend in our students to embrace challenging topics. The teams were able to propose and complete research topics of moderate to high technical difficulty. This statement is (partially) supported by a flexible learning process that embraces failure deliberately.
- We showed that a switch from traditional evaluation, such as lists of exercises, to more sophisticated evaluation based on addressing project management skills was necessary. This is supported by the results, which showed a positive feedback from students who enjoyed the evaluation and conduction of the seminar.
- The proposed methodology allowed us to evaluate teamwork, which is hard to address. By adopting agile methods into the classroom, we were able to recreate modern work environments in which teams grow and deliver value incrementally. The learning process also allowed us to evaluate hard and soft skills, which are complimentary abilities required in modern work environments.

CONCLUSIONS

We described the process of evaluating a subject in the artificial intelligence era, which is characterized by fast evolving contents and access to large amounts of online information. In order to address those challenges, we proposed a learning activity structured as a 3-step design-implement process: Project proposal and Validation, First checkpoint, and Second checkpoint. We used learning resources, such as Google classroom for communication and upload of materials, and GitHub for organizing the project documentation and kanban. Those platforms incorporate the necessary features to keep track of the learning process in a systematic and effective way (*e.g.*, reports, slides, code, kanban). The design-build activity was designed on top of three levels of independence towards reaching the learning outcomes incrementally: Unsupervised, Supervised and Following instructions. This structure is flexible and was implemented in a bottom-up approach in our case. The results showed that it is possible to evaluate rapidly evolving subjects, such as the Digital Signal Processing course module, by implementing an evaluation process based on project management and embracing failure as part of the learning process. As shown by the survey, the students were able to successfully complete their learning goals even when challenging situations were presented. In future, we can think of incorporating strategies to make the evaluation process suitable for massive classes, for instance, by implementing automatic tests at intermediate steps as checkpoints, or by considering additional teaching staff to support the process.

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