How can Generative AI Support Education?

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***Abstract*— The possible applications of GenAI (Generative AI) in education alone are so manyfold and overwhelming that it is useful to have an overview of the many possibilities that are opening up. In this paper, we try to organize some of the low-hanging fruits that can help instructors, learners, and educational managers use GenAI applications to improve educational performance.**

For instructors, GenAI can help in gaining a deeper understanding of the topics to be taught, preparing educational materials, and facilitating the enactment phase in class. Learners can be assisted in getting personalized content and feedback, having GenAI as a participant in forums, or for self-reflection and emotions detection. Managers and other stakeholders can profit from Academic Analytics, bias detection, course repurposing, and many other uses.

In this paper, we also present a use case detailing some initial actions we are implementing for a Programming with Java course. One action is to explicitly identify, in each problem set, the competencies being developed. Another one is the development of a chatbot, fine-tuned with the course material, which can be used by students as a tutor. The third action is to use a GenAI tool to generate questions aimed at assessing whether students truly grasp the programming project they have supposedly developed.

AI is here to stay, in spite of the issues it opens up, and therefore it is never too early to start experimenting with it in practice.

Keywords—Generative Artificial Intelligence, AI in education, programming course

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I. Introduction

Generative Artificial Intelligence (GenAI) has taken the world by storm. The term "Artificial Intelligence" was coined in 1956 at the Dartmouth workshop (the proposal for the workshop was written in 1955 [1]). Over the years, AI has become more attractive thanks to the popularization of machine learning applications, the availability of big data and the development of massive computation structures. The transformer neural network architecture was introduced by Google in 2017 [2], but it was only on November 30, 2022, when Open AI released ChatGPT [3] to the world for free, featuring a simple interface, that the world realized something very powerful was available capable of changing many processes and entire industries. An artificial system was able to construct plausible sentences in response to a prompt. Sometimes it would hallucinate, but overall, the responses were impressive.

Not only could natural language be generated in any language, but also all kinds of human-made formats, such as structured data, programming languages, etc. Artificial systems acquired the means of communication owned by human and would respond based on all available knowledge. Also, images, video, audio could be produced with a quality that is improving exponentially. Many industries are seeing an impact: marketing, journalism, healthcare, education, etc. [4][5].

How are educational processes going to be impacted? In this paper, we want to provide an overview of the different aspects that can be changed in education with GenAI. GenAI can be a companion to several roles involved in educational processes. We will organize the applications according to the stakeholders being affected: instructors, learners, managers, and other stakeholders. This will provide us with a rough classification, although some applications intended for one category may also be useful for other categories. Relevant examples will be provided.

II. GenAI for Instructors

GenAI can serve as a valuable assistant to instructors for understanding the field of study, preparing educational materials for the course, and implementing learning activities in class. Let's delve into these three aspects in more detail.

A. Understanding the Topics to Teach

There are multiple ways in which GenAI can support the understanding of the topic to teach. Here there are some examples:

- **Research for Course Preparation**
  This paper is about GenAI in education, not AI implications for research. Therefore, we will not talk about the immense possibilities of AI in writing research papers or even extending human knowledge, such as the discovery of new drugs [6] or new matrix multiplication algorithms and other mathematical discoveries [7]. But there are overlaps between education and research since research informs education. Teachers must understand the new developments in their incumbent field. This gets more difficult with time due to the increasingly fast advancements in research. GenAI can help teachers in summarizing the state of the art in a particular topic [8].

- **Summaries of Documents and Videos**
  An important task for instructors when creating a course is to generate the main educational material, including activities for students to practice. This typically entails instructors reviewing multiple references on the topic and filtering the most pertinent information based on the context of the course and the background of the students. GenAI tools can be utilized to process and summarize large amounts of existing information on a specific topic, whether in documents, videos, or other formats. These summaries can then serve as the foundation for developing specific educational materials for a course.

- **Proposals for Syllabi**
  Designing a new course or even the entire curriculum of an academic program is a challenging task. Each course must have its own syllabus, with its modules or topics, key concepts, learning objectives, and the competencies that students must develop. GenAI can help to draft a first outline of the syllabus of a course or even the syllabi of the courses of an entire academic program. Prompts must be well designed so that the GenAI tools act as experts in the subject matter in question and as instructional designers to help create the syllabus. Then, the content of each module or topic in the syllabus can be expanded with the help of GenAI tools (and so on until each of the synchronous sessions in the course and the corresponding student work activities are designed).

B. Preparation of Educational Material

There are many kinds of educational material that can be prepared by an instructor with the help of GenAI. Let's give some examples:

- **Documents**
  GenAI is expert in creating texts of all kinds. The texts can be structured in many ways (essays, poems, scripts, etc.), with different styles (simple, formal, academic, sarcastic, etc.), adapted to different audiences (engineering, university student, teenager, child, etc.), and presented in several output formats (sentences, paragraphs, lists separated by commas, bullets, numbers, tables, etc.). It is also possible to create text, for example, in the form of multiple-choice or open-ended questions to be used to help students practice certain concepts.

- **Mindmaps**
  Mindmaps are in essence tree representations (hierarchies) that put concepts in relation. They can help learners understand relationships. GenAI applications know typically how to represent hierarchies using intermediate structured text formats, such as LaTeX, Markdown or XML formats like OPML (Outline Processor Markup Language). Viewers for these formats help in representing mindmaps graphically (for instance, Overleaf for LaTeX [9], Markmap for Markdown [10], and Simplemind for OPML [11]) (see Fig. 1).

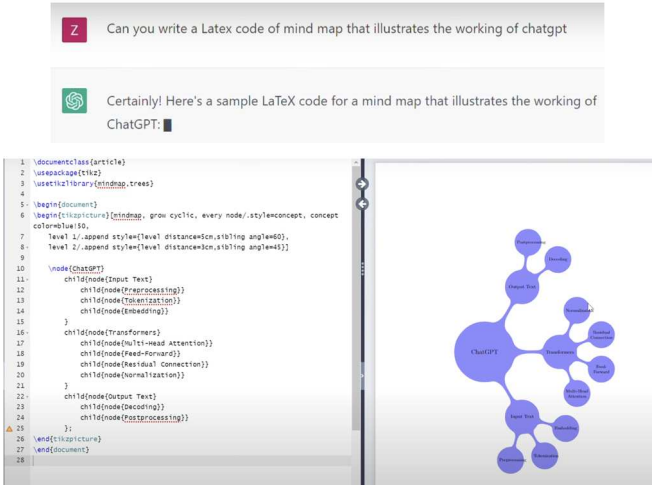

Fig. 1: Creation of a mindmap with GenAI.

- **Slides**
  Some slide file formats, such as .pptx, are (a compressed folder of) XML files; therefore, they are also considered structured text. It is no wonder that there are several applications capable of generating slides on any given topic. Some of applications give support on the design, like Beautiful.ai [12] or SlidesAI.io [13], while others help make the whole slide deck including the content, like Gamma.app [14].

- **Images**
  Images are required for illustration purposes in documents and slide decks. Previously, authors had to search for suitable images with the correct licenses. Not anymore. As is well known, images can be created with LVMs (Large Visual Models), such as Dall-e [15], Midjourney [16], or Stable Diffusion [17]. They are improving incredibly from one version to the next one. Creativity has been automatized.

- **Videos**
  There are several possibilities for creating educational videos with GenAI. First, one can get a script from a GenAI tool. This is just a detailed text that can be fed into applications like Synthesia [18] or HeyGen [19] to be spoken by an artificial avatar. This avatar can even have the image of the instructor. Then it is possible to dub existing videos (shot in real life or generated ones) into other languages, even with lip-syncing. It is also possible to create general videos without avatars.

- **Assessments and Rubrics**
  Questions, exercises, and assessments (as collections of questions), as well as rubrics, can be created using GenAI. They can be adapted depending on the student profile. Current methods for generating automatic questions can be enhanced with GenAI. Additionally, existing questions or exercises can be evaluated and improved by using GenAI to detect aspects such as clarity, difficulty, or discrimination. This process can also be combined with other non-GenAI methods for this type of detection.

C. *Enactment*

The enactment of a class can also be supported by GenAI. These are some examples:

- **Teaching Methods**
  There are a wide variety of teaching methods and strategies. The use of one or another depends on the subject matter, the learning goals, or the purpose intended by the teacher. In general, it is always more complex to design courses or sessions that make a strong use of active learning methodologies. This complexity increases with other factors, such as the number of students, the resources available, and the experience of the instructor. A GenAI tool can help the teacher by suggesting different teaching methods and strategies adapted to a given course. It can also elaborate on the implementation of the teaching methods by proposing applied examples particularized to a certain number of students, resources, and instructor experience.

- **Orchestration of a Class**
  There are multiple aspects that affect the orchestration of a class in which GenAI tools can support instructors. One of these orchestration aspects refers to the structure and timing of the class. A GenAI tool can act as an instructional designer and generate a script on how a class session dedicated to a certain topic should be developed This script can detail aspects such as: the portion of the class dedicated to lecturing key content and the portion devoted to learner practice (even alternating between lecturing and practice multiple times), the distribution of groups and roles if a collaborative activity is planned, the supplementary materials and tools to be used for content presentation, practice, and feedback collection, among other considerations. The more complex the structure and timing of a class, the more important it becomes to have a script to assist the instructor and guide the learners.

- **Feedback to Learners**
  Timely and accurate feedback can be a valuable tool for learners in completing their assignments, helping them in their learning process [20][21]. However, providing feedback for every learner may not be feasible, depending on the subject. GenAI can assist in saving time by generating a first draft of the feedback for instructors to review before providing it to learners.

- **Real-time Support to Instructors**
  Instructors can receive live guidance on their teaching methodologies from GenAI tools that evaluate their behavior in the classroom [22].

III. GenAI for Learners

The integration of GenAI into education is changing the learning landscape, transforming the way learners acquire knowledge and skills. GenAI is a great companion for informal learners and for students registered in a formal institution. Instructor-learner interaction as well as interaction among learners are key to learning. We can now introduce a new actor in this interaction: GenAI. AI capabilities to analyze data and personalize experiences is also changing the education into a more effective learning space for learners. Now learners can have a 24/7 assistant that can personalize their learning experience.

- **Rephrasing and Interpretation**
  A learner can make use of GenAI to request the rephrasing of texts, such as using simpler terms or providing examples. GenAI is a master in language manipulation, therefore it can make complex texts understandable. This interpretation facet also applies to images and graphs. In figure 2 taken from [23], one can see a stack of traffic signs that regulate parking times, which is quite difficult to interpret. When asked for a particular time, the AI responds. Consider now the diagram shown in Fig. 3 [24]. A GenAI can explain this diagram giving a lot of insight, as can be seen in Fig. 4.

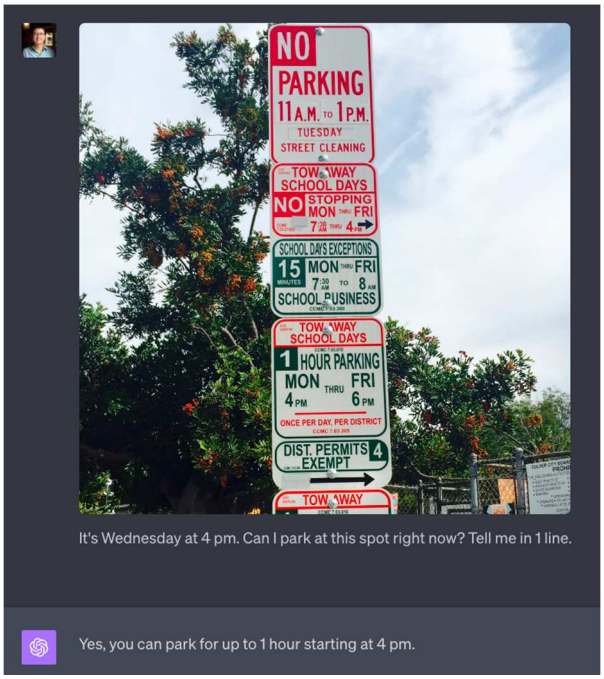

Fig. 2: Traffic signs

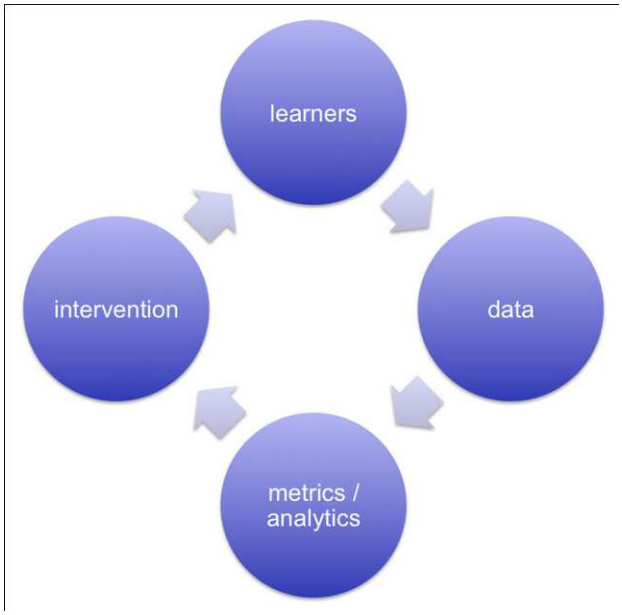

Fig. 3: A diagram

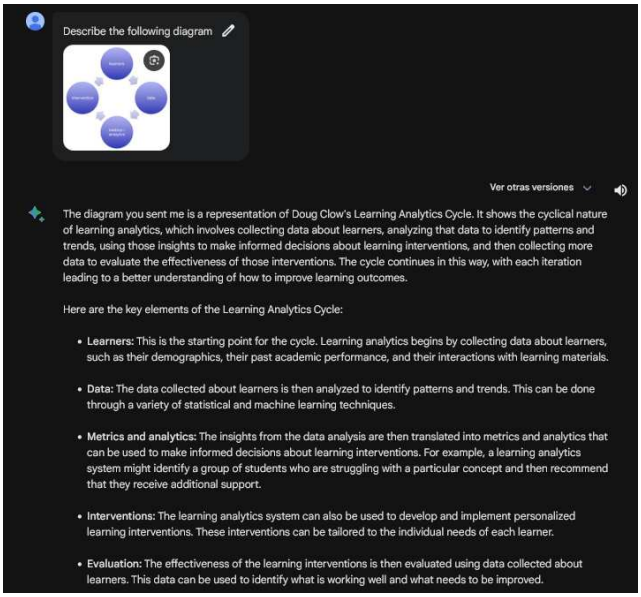

Fig. 4: Interpretation of the diagram of Fig. 3

- **Personalized Content**
  Educational content does not have to be static; there are numerous possibilities. The capabilities of GenAI can streamline the process of adjusting educational materials to cater to individual learning preferences, pace, capabilities, resources, and approaches, providing immediate feedback and assistance. GenAI can contribute not only to promoting more effective learning but also to better accommodate diverse learning needs, including students with disabilities. Nowadays, learners can build their personalized Generative Pre-trained Transformers (GPTs) easily. By providing the content related to a specific subject, learners can develop their own GPT tailored to a particular domain. This level of personalization improves the assistance learners can have using the power of GenAI.

- **Mentoring**
  One-way explanations are often not enough for learners to fully understand the educational content. A further personalized interaction is often needed. GenAI can help for this task. Khanmigo [25] is such an online tutor. Khanmigo is fine-tuned in such a way that it does not give the answers to problems. Rather it helps the learner in the learning process as a Socratic tutor would do.

- **Forums**
  Forums are useful for online education as well as in-person education. Students can ask questions. Other students can answer as well as the instructor. A possibility is now to include a chatbot in the conversation. This is what David Malan at Harvard has done for his introductory course in programming CS50 [26]. Chatbots could get answers wrong, but so do students. The chatbot should be properly fine-tuned. GenAI can guide the student on a personalized learning path, offering assistance and acting as a virtual tutor, providing instant feedback [27], answering questions, and guiding students through their learning journey. This allows for a more interactive and supportive learning environment. Students consider GenAI tools, such as ChatGPT, to be useful due to their accessibility and ease of use. However, they also perceive them as supplementary resources to their learning path [28].

- **Special Education**
  The World Health Organization (WHO) reports that more than one billion people globally live with disabilities. Without proper assistive technology, these individuals may not be able to engage in education, lack job opportunities, and lead an independent life [29]. Over the past few years, AI has shown considerable effectiveness in assisting learners with disabilities to actively participate in education. [30].

- **GenAI as a Learner**
  GenAI tools can play any role, so why not let the tool take the role of a learner and have the learner teach. Teaching is one of the best ways of learning.

- **Self-Reflection on Meta-Cognitive Skills**
  It is very important for students to be able to self-reflect on their learning process, particularly regarding their own meta-cognitive skills related to learning. In this regard, GenAI can be used to detect students' meta-cognitive skills, such as help-seeking behavior (by analyzing whether the text of students is well-oriented towards achieving a solution, retrieving the text from various sources, such as forums or specific text boxes for additional comments or activities), or goal setting (by analyzing text and determining whether students set goals correctly and if they outline the corresponding steps towards them). These GenAI techniques can be used alone or in combination with non-GenAI existing techniques to detect meta-cognitive skills, e.g., for help seeking [31][32] or for setting goals [33], giving more flexibility depending on the available tools in each scenario.

- **Students' Emotions**
  The detection of students' emotions is important to enhance the learning process. Students' emotions can be detected with existing non-GenAI techniques [34], but these techniques apply to specific learning scenarios. In addition, the detection of emotions can be performed using GenAI tools that analyze text from various sources. GenAI techniques, along with other AI techniques, can be used in combination for this purpose.

IV. GenAI for Managers and Other Uses

GenAI can also be used as a companion to educational institutions, supporting several of their processes. We also include in this section other uses of GenAI in education that apply to other stakeholders or to several of them.

- **Chatbots**
  Specific chatbots can be created for different services or units of the educational institution, both to support their staff, as well as to support external personnel who want to ask questions about public information provided by these services or units. For example, CharlieBOT [35] is a chatbot specifically designed to answer questions from the IT and Communications Service at UC3M. The current version of CharlieBOT uses the GPT-3.5-Turbo Large Language Model (LLM), which supports up to 16,000 tokens, and embeddings. Every question received by CharlieBOT is sent to the model, together with the entire previous conversation (as long as it does not exceed the maximum number of tokens), and a context for the semantic search result and a definition of how the bot should behave.

- **Academic Analytics**
  AI has been used already for several years to support academic analytics, for example, to try to predict student behavior in an academic degree, especially in terms of dropout or need for reinforcement. Early warning systems have been developed for this purpose [36]. Now, GenAI can also be used to generate detailed reports with the problems detected for each student by the early warning system. These reports can be used to improve student awareness, to support decision-making by Head of Departments or can serve as input for other content recommendation systems or systems that support students in the development of their self-regulated learning strategies.

- **Lifelong Learning**
  Universities must rethink and adapt their educational offer in relation to the upskilling and reskilling of professionals, especially in a context in which more and more short learning opportunities are demanded. The proper connection of learners with micro-credentials that meet their career goals, educational background, and lack of knowledge and skills demanded by the labor market becomes very necessary. Several approaches have recently been released in this line, including Xpert by edX [37], which focuses on course discovery within the edX platform, and the system on LinkedIn for connecting with courses offered at LinkedIn Learning.

- **Automatic Repackaging of Courses**
  Universities have generated large amounts of content in recent years in multiple formats (text, video, podcasts, etc.), especially after the wave of MOOCs (Massive Open Online Courses) and the subsequent SPOCs (Small Private Online Courses) [38]. These contents are sometimes embedded as part of courses, but these contents may have value independently and can even be part of other courses. GenAI tools can support instructors and instructional designers in repackaging content automatically, taking whole lessons or parts of lessons to form new courses, increasing the available educational offer of the university.

- **Summaries**
  Summarization is not just important for instructors to understand the state of the art of a field. Accessing a summary of a document or video is useful for everyone, instructors, learners, managers, citizens in general. In a context of overabundance of information, which is going to be extended even more due to GenAI, it is important to capture the essence of informational material in short.

- **Complete Courses**
  It is even possible to create complete courses from a document, video, or sets of these thanks to GenAI. A complete course typically contains content that the learner must read or watch, as well as activities to practice. Tools such as Nolej [39] allow the creation of complete courses. This GenAI tool starts from a document or video and creates a summary, glossary of key terms, flashcards, as well as interactive activities such as quizzes, crossword puzzles or word search puzzles. Nevertheless, it is important that these courses can be seamlessly integrated in traditional LMSs (Learning Management Systems) using common formats and frameworks, such as H5P, which is supported by Nolej to export the course, as well as by most common LMSs, such as Moodle, Canvas, Blackboard, or Open edX.

- **Learning Analytics**
  Learning Analytics processes can be enhanced with GenAI in several ways. First, data about usage of GenAI tools by both instructors and learners can enrich the information about learners, which can boost the performance of current machine learning models. Moreover, these tools can also support the analysis of data (e.g., unstructured data) to improve the detection of behaviors and can also support the generation of dynamic representations of the learning (e.g., sequences based on text reflections or illustrations) or synthetic data. Furthermore, these tools can enhance learning analytics visualization, which can incorporate more elaborated explanations [40].

- **Detection and Correction of Bias**
  Different biases on learning processes and platforms can be better detected and solved using GenAI. For example, the detection of cheating on learning processes, e.g., the work in [41] can be enhanced with the analysis of text with GenAI.

V. CASE STUDY

We now present a case study for the use of GenAI. It refers to a first year, second semester, Java Programming course offered in four Engineering degrees in the Telecommunications area, both in English and Spanish, at Universidad Carlos III de Madrid (UC3M), Spain. This Java Programming course builds on solid teaching and learning material created throughout several years. This material contains a set of videos and exercises offered through the Open edX platform as a SPOC (Small Private Online Course) in addition to a problem sets as well as exams with solutions from previous years. The videos and exercises that are organized as a SPOC were collected from a series of MOOCs offered in edX and generated by the instructors of the course [42]. Over the years the material in this Java Programming course has been used to generate several chatbots that offer students the possibility to review related programming concepts [43] or receive questions that take into account student's knowledge level and the difficulty of questions applying Item Response Theory [44].

GenAI is being currently used for three main purposes in the context of this Java Programming course. The first purpose refers to the generation of new content to complement programming tasks that students must do as part of the course lab. It should be noted that nowadays students can use GenAI tools such as ChatGPT or GitHub Copilot to solve programming tasks in a fast and straightforward way. This is not necessarily a bad thing, as long as they learn in the process and develop the ability to develop their own code, find potential bugs, and detect code that does not conform to the given requirements. To encourage learning and reflection on the programming tasks performed we have taken the problem sets of the course and asked ChatGPT to generate multiple reflection questions for each of the problems aligned with the competences that the instructor wants the students to acquire. The goal is that students reflect on the code developed and the main concepts associated with this code once they have finished the lab session. Reflection questions may also request students to make changes in the code so that they can reflect on the implications of these changes. A Python script has been generated to take the PDFs of the problem sets, process them, send the text through the ChatGPT API, and store the answers received. Several temperature values were tested in the requests to the ChatGPT API to obtain variations of the questions that promote greater reflection on the practice statements.

The second purpose refers to the creation of a chatbot to specifically assist the students in this Java Programming course so that they can ask questions to this chatbot and get answers aligned with the course content. This requires the fine tuning of an LLM (Large Language Model) taking the educational material of the course, that is, videos (their subtitles), exercises, problem sets, exams, etc. First attempts were made to fine-tune Llama 2, as an open source LLM by Meta, in particular the sharded Llama 2 model with 3 billion parameters (3B). The conclusion is that Llama 2 can be used on the Google Colab free version getting good answers, although the Llama 2 3B sharded model can only be used with simple datasets (i.e. low number of samples and a short length). In addition, Google and Microsoft recently offered the possibility to create chatbots by fine tuning some of their LLMs. For example, Google offers Vertex AI and allows fine tuning some of their models (such as PaLM 2 and Gemini). Microsoft offers Azure OpenAI Service to fine tune, for example, the GPT-3.5-Turbo model.

The third purpose is to support the assessment of students' knowledge and competencies in the Java Programming course. Nowadays, instructors have no guarantee that the work submitted by students has been completed by the students themselves and not directly by a GenAI tool. This is especially critical in programming courses where students are traditionally expected to develop code as part of larger and comprehensive projects. Even if students have used a GenAI tool to generate code, they must comply with the institutional policy on the use of GenAI tools and demonstrate their knowledge and skills by answering questions about their own work or doing small variations on the code. This demonstration of knowledge and skills should be done in an environment supervised by the instructor, for example during a face-to-face lab exam or during an interview. However, in a first-year programming course, which typically has a large number of students, the proposal of questions and variations for each student's code scales very poorly. Nevertheless, instructors can upload students' code to a GenAI tool to get questions or variations to be used for the interview phase. This allows for better scalability of the supervised assessment of students' knowledge and skills in the Java Programming course.

VI. CONCLUSION

Generative AI can work in *partnership* with many stakeholders in the educational ecosystem. The idea of *partnership* has been harnessed by many companies when naming their products: Microsoft has *copilots* for different purposes. Google has given the name *Duet* to the AI-enhanced Workspace (Docs, Sheets, Slides, etc.). We have described many applications that are evident at this moment, but we believe that many more will come up in the future. We must understand that GenAI is not just what ChatGPT can offer today. ChagGPT is just an instance of what is possible. The possibilities and therefore the applications are much wider.

At any rate, it is important to train instructors, learners, and managers on how to use AI. The response depends very much on how the prompt is phrased. Prompt engineering is a must for all although the GenAI tools themselves can help to generate the prompts [45]. We plan to include in the future many more uses of GenAI in our courses. We believe that our students, as graduates, will need to master the skill of being assisted by GenAI. Therefore, in addition to teaching the expected content, we feel that it is never too early to provide practice in using GenAI tools.

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