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"Who will be left behind?": A Swedish case of learning AI in vocational education

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ABSTRACT

Increasing numbers of job roles emphasise skills related to Artificial Intelligence (AI). Alongside this trend, AI education has been incorporated into curricula at all levels, from K-12 to higher education. However, how to teach AI knowledge and transfer this knowledge into practice, especially to vocational students, remains under-investigated. To address this research gap, we first examined the goals and components of an AI curriculum that has been running for more than three years in Sweden. Then, we interviewed fourteen vocational students from different cohorts within the curriculum about their learning experiences. We found that the students expected more personalised learning and guidance from dedicated instructors, and a better curriculum structure. Further to this, many students wanted to learn more practical skills; it also became clear that technical training, sustainability, and reflection opportunities were given surprisingly little consideration. Building on the results of this case study, we provide recommendations for the future integration of AI into vocational education.

1. Introduction

In computer science, there is a school of thought dedicated to engineering computers to solve complex tasks autonomously and to imitate (or even replace) human decision-making (Weizenbaum, 1976). This field is known as **Artificial Intelligence** (AI) research. Techniques used to achieve such automation and intelligence include logical inference via formal languages, machine learning based on examples and pattern extraction, and deep learning using artificial neural networks (Capel & Brereton, 2023). Historically, AI was of interest to a relatively small group of computer scientists and was primarily discussed within the scientific community (Zhang & Lu, 2021), gaining broader attention only when breakthroughs made headlines.

The latest developments in AI, especially with the popularity of **Generative AI**[2], are reshaping the global job market (Acemoglu, Autor, Hazell, & Restrepo, 2022). Many jobs previously performed by humans, such as customer service, can be potentially replaced or altered with AI applications (Klarna, 2024); as a result, jobseekers are competing with AI applications in the job market (Guarascio, Reljic, & Stöllinger, 2023). Research suggests that some tasks in marketing, humanities, legal services, and securities may be performed more efficiently through AI (Felten, Raj, & Seamans, 2021). Similarly, another study postulated that **32.8%** of occupations could be *fully impacted* by ChatGPT, whereas **36.5%** may *experience a partial impact*, and **30.7%** are likely to

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2 Generative AI: refers to applications that generate realistic and contextual output by analysing the underlying patterns and distributions of training data (Jovanovic & Campbell, 2022).

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remain unaffected (Zarifhonarvar, 2023). The study mentions software developers, computer programmers, data scientists, media and legal professionals, and customer service representatives as especially affected by ChatGPT (Zarifhonarvar, 2023). The widespread disruptive adoption of AI transforms existing professions and forces educational institutions to adapt and provide students with knowledge and skills for succeeding in an increasingly technologically driven, volatile job market.

Teaching students to use AI applications at various educational levels to prepare them for the workplace remains a challenge (Southworth et al., 2023). Educators commonly emphasise and agree on the importance of designing appropriate AI curricula according to student literacy in studies on AI education for K-12 and university students (Bewersdorff, Zhai, Roberts, & Nerdel, 2023). Tailoring AI curricula to specific demographic groups through effective teaching methods, appropriate tools, and cross-disciplinary resources is essential for the success of AI education (Lee & Kwon, 2024). While academic AI curricula typically focus on theoretical foundations, are prolonged and require much time to reevaluate and adjust, vocational AI programs are frequently designed to be expedited and agile to keep up with rapid changes in the job market.

Vocational education and training (**VET**) programs aim to increase student employability to meet labour market demands (Zahilas, 2020) in a short amount of time. However, there are few studies on how VET programs have responded to AI developments by adapting curricula, and their impact on student AI literacy is poorly understood. To address this gap, we formulated the following two research questions (RQs):

- RQ1: What are vocational students' perceptions and learning experiences of an AI curriculum?
- RQ2: What challenges and benefits do students experience when using AI to support their educational and professional development?

We conducted a case study with vocational students enrolled in an AI curriculum at a Swedish vocational education institute. As Sweden has a high level of digitalisation and a long history of vocational education, AI-related skills and knowledge are already being included in some VET programs (Yrkeshögskolan, n.d.). To address our research questions, we reviewed the curriculum of one VET program with AI as its core component and interviewed fourteen students from various cohorts within the program about their learning experience.

In the following sections, first, we provide an overview of related works focusing on AI curricula at different stages of education and introduce vocational education and training in Sweden; additionally, we review the goals and components of the examined AI curriculum. Next, we present the methodology of the study in Section 3; and we present findings from our interviews according to the research questions in Section 4; finally, we discuss the results in light of their application to the further development of AI curricula in vocational education.

2. Background

2.1. AI curricula in different stages of education

AI education can be conceptualised as the development of skills and competencies of an individual needed to adapt to the rapid deployment of AI (Attwell et al., 2020). It is of no surprise that VET schools became one of the earliest adopters of such AI education programs. Kandlhofer, Steinbauer, Hirschmugl-Gaisch, and Huber (2016) identified categories of AI literacy topics matching educational stages, from Kindergarten to University. AI literacy can be defined as "a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (Long & Magerko, 2020, p. 2). This widely cited definition highlights an individual's competence in critically evaluating, collaborating with, and applying AI in different scenarios.

The design and implementation of curricula impact education at all stages. Hutson and Ceballos (2023) suggested balancing technical and soft skills development when designing AI curricula, since focusing solely on teaching AI's technical aspects is insufficient for learning how to communicate and work in teams. To address this, they recommend integrating competency-based, project-based, experiential, service, and work-based learning in AI education (Hutson & Ceballos, 2023). Another study identified key topics that should be incorporated into undergraduate education curricula: basics of AI, machine learning, computing, multidisciplinarity, data-competence, AI capabilities, responsible AI, and Human–AI Interaction (Tenório & Romeike, 2023).

Traditionally, AI education has been geared towards computer science majors, but there is now more demand from students in other fields, driven by interest in key concepts and applications of AI, its career benefits, and cross-disciplinary relevance (Laato et al., 2020). A literature review of AI in higher education found that AI tools were most commonly used in language learning (17%), computer science (16%), management (14%), and engineering (12%) (Crompton & Burke, 2023). While students found AI language tools useful for seeking information, summarising, and elaborating academic concepts, they also expressed ethical concerns about cheating and fair use of AI in assessments (Ou, Stöhr, & Malmström, 2024). A survey of Australian university teachers revealed that 70% were concerned that Generative AI could foster student over-reliance on the technology (Lee et al., 2024).

Most studies have focused on AI curricula in either K-12 or higher education (Alfredo et al., 2024). A mixed-method study, Chiu et al. (2021) showed that a co-created AI curriculum covering AI introduction, big data, machine learning, cloud computing, AI ethics, and societal impact improved K–12 students' perceived competence, attitude, and intrinsic motivation towards AI. A systematic review of AI education in K-12 classrooms concluded that it generally enhanced student learning outcomes, motivation, attitudes towards AI, interest in technology, and engagement with career explorations (Lee & Kwon, 2024). Effective teaching methods, hands-on activities, integration with other subjects, and addressing misconceptions were highlighted as important factors

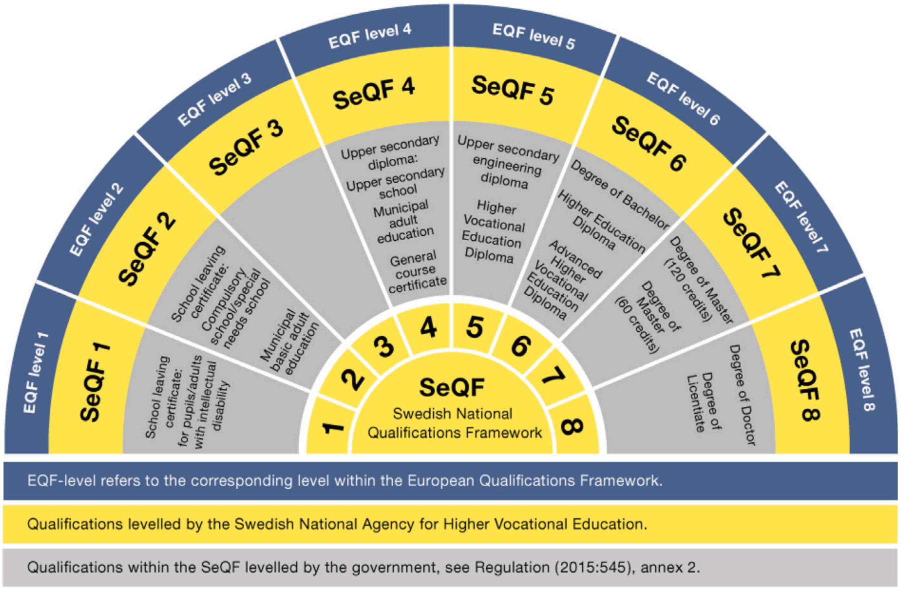

Fig. 1. The Swedish qualifications framework for lifelong learning (MYh, 2025).

for successful AI education (Lee & Kwon, 2024). Through co-design workshops with educators, Lin and Van Brummelen (2021) found that despite ethics being included in AI curricula, educators hesitated to implement ethics activities in classrooms. A survey of Nigerian secondary school students emphasised teamwork and human-tool collaboration through course content as important competencies for AI literacy (Sanusi, Olaleye, Agbo, & Chiu, 2022).

Researchers highlighted the critical role of VET in facilitating reskilling and upskilling, enabling individuals to adapt to the evolving business landscape in the AI era (Lim & Lee, 2024). Despite the growing attention to vocational education, empirical studies on AI education in VET are limited (Rott, Lao, Petridou, & Schmidt-Hertha, 2022; Tommasi, Perini, & Sartori, 2022). A mixed-methods study in Germany highlighted the importance of including both AI theory and practical use in teaching curricula (Rott et al., 2022). The combination of practical use of software applications with explanatory videos supported the students' learning (Rott et al., 2022). Vocational training experts stressed the need for STEM competencies (science, technology, engineering, and mathematics) alongside technical and transversal skills in VET programs (Tommasi et al., 2022). In sum, while several studies on AI education offer insights for developing AI programs in K12 and higher education, there is a need for further empirical research on student learning experiences within AI VET programs to guide the development of appropriate curricula (Grover, 2024). With AI advancement affecting many vocational careers, like entry-level programming and visual design, our study is both timely and significant.

2.2. Vocational education and training in Sweden

Swedish VET programs have traditionally been one of the career trajectories after compulsory upper-secondary schooling. Fig. 1 provides a detailed summary of current forms of post-secondary and tertiary education in Sweden and compares the equivalent levels on both the European Qualifications Framework for Lifelong Learning (EQF) and the Swedish Qualifications Framework (SeQF). Vocational education in Sweden followed the so-called "Swedish model" that was connected with a strong welfare state (Köpsén, 2022a), where students either entered a certain profession after graduation or gained credits for higher education. In the last couple of decades, VET, similar to other education levels in Sweden, transformed from a traditionally integrated and egalitarian model to a more market-based one (Olofsson & Panican, 2024).

In general, VET can be divided into two main models: a dual model with alteration between school and work, adopted by countries like Norway, Denmark, Switzerland, and Germany, and an apprenticeship model, adopted by countries like Canada, USA, UK, and France (Cournoyer, Fournier, & Masdonati, 2017). In comparison to other Nordic neighbours or European countries like Germany and France, VET education in Sweden has been characterised by a weaker apprenticeship tradition (Olofsson & Panican, 2024). In general, Sweden's model of VET education could be characterised as more hybrid, since the educational reform of 2011 introduced apprenticeship training in addition to the already existing school-based VET (Olofsson & Panican, 2024).

Similar to other countries, Sweden has begun to use competence-based education (CBE) instead of academic disciplines (Wesselink, Dekker-Groen, Biemans, & Mulder, 2010) as a base of VET curriculum building. Competence, in turn, is often defined as "an integration of knowledge, skills, and attitudes that enables a person to perform a certain task in ill-defined and unique environments" (Wesselink et al., 2010, p. 816). The focus on CBE within VET led to the shift of preferences in terms of learning outcomes towards the main goal of students' self- and lifelong learning, with teachers playing the role of their coaches. Despite the almost uniform shift to CBE curriculum building within VET, there is little empirical evidence about its effectiveness (Wesselink et al., 2010).

Earlier in 2002, a new form of upper-secondary education, higher vocational education (**HVE**), was established, introducing decentralised programs and curricula (Köpsén, 2022a). To establish a new HVE program, education providers, together with employers from industry, must first propose the program to the National Agency for Higher Vocational Education, which, in turn, decides whether the program meets the needs of the labour market and can be funded for up to five study periods (OECD, 2022). HVE schools can be run by both private and public education providers. The number of private HVE providers is steadily increasing, with the share of private providers having increased from 50% to 60% in the period of 2007–2023 (Statistisk, 2024).

HVE programs usually last for 80 weeks and culminate with a six-month internship, which is considered to be a part of the work-based learning (WBL) requirement. Residence permit holders attend these programs for free (if the Swedish National Agency for Higher Vocational Education approves the program) and are eligible for student grants and loans. Due to HVE's strong market orientation (Köpsén, 2022b), some schools now offer courses and programs in English, attracting many transnational, fee-paying students (Metreveli, 2024). A key aspect of HVE is the absence of permanent teaching staff, with industry leaders, guest speakers, and program managers handling all instruction and aligning it with employers' demands (Köpsén, 2024). Meanwhile, employers in the provision of HVE act as "powerful recontextualising agents in the formation and management of the programs, as judges of the market value of the outcome of training – the students – and as support for the providers in a competitive training market" (Köpsén, 2024, p. 6).

Despite the general agreement that the Swedish VET system has many strengths, such as a strong evaluation system and flexibility of its provision, it is constantly challenged by growing pressure from industry affected by labour shortages and challenges due to digitalisation and automatisation of workplaces, as well as an increase in students from more diverse backgrounds (Małgorzata & Shinyoung, 2019) and mediocre graduation rates, with only 67% of students graduating from their HVE programs by 2022 (Statistisk, 2024). Moreover, while VET is often associated with more stable employment and labour conditions, the number of students choosing this educational trajectory continues to decrease (Olofsson & Panican, 2024). Among the countermeasures to address these issues, some specialists argue for a stronger collaboration across VET schools and an overall redistribution of VET provision to fewer institutions, as well as strengthening the progression from upper-secondary VET to post-secondary education (Małgorzata & Shinyoung, 2019).

This study examines students' learning experiences with an AI curriculum at **SV** (pseudonym), a well-established private Swedish HVE school. Admission is based on practical tasks, emphasising hands-on experience over academic history or language proficiency. SV prioritises experiential learning, combining elements of problem-based learning, case-based learning, and team-building exercises. The school employs no permanent or licensed teachers; instead, "industry leaders" – professionals active in relevant fields – lead the education, blending conventional lecturing with group activities. The curriculum is structured into thematic "modules", with group projects and self-paced learning as its key components. SV also hosts "design sprints", where companies present students with real-life tasks to "solve" and promote collaboration across programs — events closely resembling hackathons.

2.3. Goals and components of the examined curriculum

SV debuted its AI curriculum (**SVAI**) in Fall 2020. The 80-week program includes 13 modules, cross-program design sprints, an individual project, and an internship. According to the SVAI curriculum, the program supplies skills needed for a hybrid role in which students act as interpreters between business opportunities and AI advancement. While they emphasise the need for in-depth knowledge of data and statistics, the program departs from traditional learning, focusing on evaluating AI's benefits and limitations in business. The curriculum highlights the development of entrepreneurial skills, leadership, group dynamics, and effective teamwork. External AI professionals assess students via oral presentations, providing industry-relevant evaluations of their competences. The modules cover a range of topics, from "AI principles" to niche areas like "ecosystem of the AI landscape" and "business consulting in AI". The program seeks to equip graduates with both the theoretical underpinnings and practical applications of AI in business contexts. The SVAI completion certificate states that its holder can be employed as an AI Business Consultant, AI Designer, Digital Business Developer with AI, IT Strategist with AI competence, and AI and Emerging Tech Developer.

According to the syllabus, the program comprises four courses: Course One (six projects, 22 weeks), Course Two (six projects, 23 weeks), Course Three (individual project, eight weeks), and Course Four (industrial placement, 27 weeks). In summary, the first semester covers broad AI topics, from its landscape to innovation, while the second focuses on business development and technical skills. Students are assessed individually after each course through various formats, including presentations, reflections, essays, and written reports. The Assessment is based on course goals associated with the competencies required for their target profession.

Similar to most Swedish VET programs, SVAI is supposed to cover four components of CBE such as curriculum, pedagogy, assessment, and career competencies (Wesselink et al., 2010); the curriculum course goals are categorised into three main areas: knowledge, skills, and competencies. The six competencies that the SVAI curriculum intends to develop are:

1. Independently pursue developing a product, service, or process that includes AI in a way that furthers your own professional development.
2. Manage your own learning needs to continued professional development.
3. Manage a project within AI in terms of time, resources, and requirements.
4. Apply and reflect on tools which support increased self-awareness, group development, well-being and effective communication.

Table 1
Demographic information of the participants.

Participant	Gender	Age	Achieved Education	New Arrival	Worked in Tech	Worked in Business
P1	Male	25–34	High School	no	yes	no
P2	Male	45–54	Master's Degree	no	no	yes
P3	Male	25–34	Master's Degree	yes	no	no
P4	Male	35–44	Master's Degree	yes	yes	no
P5	Female	25–34	Bachelor's Degree	no	no	no
P6	Female	18–24	High School	no	yes	no
P7	Female	35–44	Master's Degree	yes	yes	no
P8	Male	35–44	Bachelor's Degree	yes	no	no
P9	Male	25–34	High School	yes	no	no
P10	Female	25–34	High School	no	no	no
P11	Male	25–34	Bachelor's Degree	no	yes	no
P12	Female	35–44	Master's Degree	yes	no	yes
P13	Male	35–44	Bachelor's Degree	yes	no	no
P14	Male	45–54	Master's Degree	yes	no	yes

5. Work as an effective team member and leader in cross-functional, onsite, and distributed teams.
6. Communicate throughout the project using methods adapted to the intended audience, effectively managing relationships and expectations with key stakeholders in the project.

It is worth noting that, among the six competencies identified, only two focused on AI skills related to professional development and project management, while the rest appear to be transferable to many careers, emphasising elements such as self-paced learning and teamwork. Overall, the SVAI curriculum aligns with the ten principles of the Comprehensive Competence-Based Education (CCBE) Framework (Misbah, Gulikers, Dharma, & Mulder, 2020; Sturing, Biemans, Mulder, & De Bruijn, 2011): (1) the program is based on vocational core tasks, working processes, and competencies; (2) complex vocational core problems are central to learning and assessment tasks; (3) learning activities take place in different, meaningful vocational situations; (4) knowledge, skills, and attitudes are integrated into learning and assessment; (5) students' development is regularly assessed for various purposes; (6) students are challenged to reflect on their own learning; (7) the program is structured in such a way that the students increasingly self-steer their learning; (8) the program is flexible in that it allows students to learn and progress at their own pace; (9) teachers guide student learning and this guidance is adjusted to the learning needs of the students; and (10) the study program pays attention to learning, career, and citizenship competencies.

A closer examination of the ten CCBE principles, however, raises additional questions in relation to the first and last two principles. Thus, the investigation into the SVAI curriculum as intended, implemented, and attained curricula (Van den Akker, Kuiper, Hameyer, & van den Akker, 2003) can highlight the role of these principles in HVE educational settings, where there are no professional teachers and only a limited emphasis on technical AI competencies. Since two out of ten CCBE principles are centred around teachers' competencies as a coach, mentor, and expert, as well as being familiar with the qualification profile, the fact that SV does not employ permanent teaching staff and focuses on the industry leaders' professional background rather than a pedagogical one, this raises concerns whether the institution can meet these principles effectively. Meanwhile, when it comes to the last principle, it is not clear which citizenship competences should be attained by the students, granted that the education is provided within the transnational English-medium instruction (EMI) setting. More importantly, it does not address the specific transnational context of the program, where global citizenship competences such as sustainability and ethical use of AI should be balanced with local concerns.

While the goals and components of the AI curriculum appear to mostly align with the CCBE framework, the actual learning experiences of students and the impact of this curriculum on students' AI knowledge and skills remain unclear.

3. Method

3.1. Participants

We recruited our participants with a survey distributed through SV's online communication tool in December 2023. Of the 29 students who completed the survey, 16 were from SVAI. We successfully interviewed 14 of them (9 male, 5 female) in January 2024. Participants, current or former SVAI students, ranged in age from 18 to 54, with seven between 18 and 34. Their highest-achieved education varied: four had high school diplomas, four held Bachelor's degrees, and six had master's degrees. Eight participants were new arrivals to the Swedish society. It means they had not been living in Sweden for more than five continuous years. Eight participants had work experience in Sweden, five in tech-related roles, including one with experience at a major tech company, and three had business-related experience. See Table 1 for demographic details.

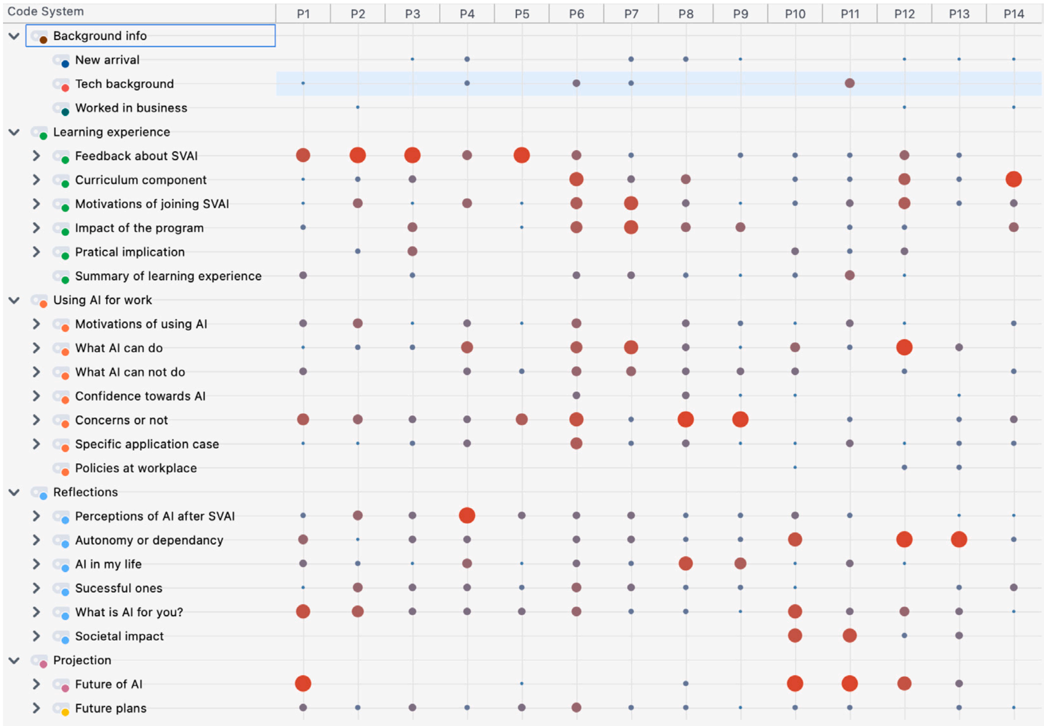

Fig. 2. Visualisation of coded transcripts. (Note: the symbol size indicates the relative weight of coded segments attributed to each participant).

3.2. Procedure

Based on previous research on AI literacy and education (as described in 2.1), we developed our interview protocol. We chose to focus on the following three themes (Long & Magerko, 2020; Rott et al., 2022):

- *Learning experience in the program*: motives for joining the program, overall experience and impact, and how interviewees apply what they learned.
- *Usage of AI for work purposes*: what works and what does not with AI applications in their professional life, as well as their confidence, concerns, and motivations for incorporating AI at work.
- *Reflections on the learning program and AI use*: successful profiles, future plans, the usefulness of AI in daily life or work, dependence on AI, and the question, “What is AI for you?”

We pretested the interview protocol with two researchers specialising in AI education before data collection. The full protocol is included in A.2. All interviews were conducted remotely via Zoom. The interviews were audio-recorded with participants’ verbal consent, after receiving information about the study goal, data collection, data process, and their rights.

3.3. Ethics considerations

The study was approved by the Ethical Review Panel at the University of Luxembourg prior to data collection. We collected anonymous survey responses and audio recordings of interviews, with participants being informed of the study’s purpose and their right to withdraw (refer to A.1). Written consent was obtained before data collection for the survey, and oral consent was obtained for the interviews. Only pseudonymised transcripts were used for data analysis. Each participant received a €15 gift voucher for their dedicated time.

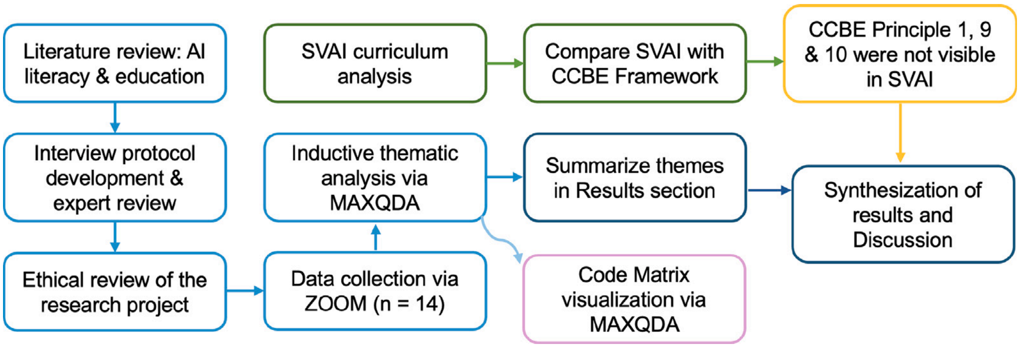

Fig. 3. Flowchart illustrating the different stages of the study.

3.4. Data collection and analysis

The SVAI syllabus was downloaded from SV's public website. The interviews lasted an average of 39 min (SD = 9 min), totalling nine hours (see Fig. 3 for a visualisation of different stages of our study). The audio recording was transcribed using Microsoft's automatic transcription service, the transcripts were then manually reviewed for accuracy. We applied inductive thematic analysis, following the six phases suggested by Braun and Clarke (2021): (1) data familiarisation; (2) data coding; (3) initial theme generation; (4) theme development and review; (5) theme refining, defining and naming, and (6) summarising findings.

First, three authors read the same three transcripts to familiarise themselves with the data and highlighted meaningful segments. After two meetings discussing these segments, the team defined overarching code categories and generated initial codes in MAXQDA software (VERBIsoftware, 2024), merging duplicates to create a unified code system. Second, each author independently coded one-third of the remaining 11 transcripts using the established code system, adding new codes as needed. The new codes (marked with a different colour) were integrated into the initial categories and discussed among the authors (refer to B to see the final coding scheme). Third, after finalising coding, we conducted peer reviews to ensure consistency. A fourth author reviewed all transcripts as part of this quality check. We then summarised themes relevant to our research questions and began manuscript writing. Finally, we used MAXQDA's Code Matrix Browser to visualise the coded segments by participant and theme (see Fig. 2). Larger symbols, based on the weight filter, indicate higher frequencies of a code for a participant, reflecting varying thematic emphasis among participants (e.g., P10 showed a strong presence in reflection and projection).

3.5. Quality criteria for qualitative study

We designed our study following the criteria for qualitative research proposed by Tracy (2010), evaluating our research plan on parameters such as topic importance, rigour, sincerity, credibility, resonance, contribution, and general coherence of the plan. To do so, we conducted a comprehensive literature review on AI education in various settings (higher and vocational education) and across different countries, focusing on the intersection of Sweden's short-term AI curriculum with vocational education as a model. To ensure transparency, we made our full protocol open, and shared our interview guidelines and coding scheme with the research community. Our study took an exploratory, inductive-based approach (Braun & Clarke, 2021; Clarke & Braun, 2017); therefore, our work was embedded within the qualitative paradigm that treats findings as situated and the researcher as subjective interpreter of meaning (Braun & Clarke, 2021). Thus, our data analysis focused on identifying emergent themes and patterns rather than on quantifying the occurrence of the topics. This epistemological position was informed by the suggestions of Braun and Clarke (2013, 2021) on thematic analysis. At the same time, some themes appeared recurrently during our analysis, we decided to make visual presentations of the findings (see Fig. 2), helping to balance qualitative and quantitative presentation of the data.

4. Results

4.1. Learning experience: gains, challenges, and successful profiles

4.1.1. Gains: development of soft skills, self-paced learning, teamwork, and new opportunities

Students mentioned valuable provision and training in soft skills: preparing for project presentations, participating in networking activities, and managing course projects. Additionally, the participants discussed their increased confidence in self-paced learning, e.g.: "I changed my approach to many aspects of my private life or even working life, I reinforced my assumption that I am able to learn" (P8). The examined institute, described as a "hub of knowledge" (P3), helped the students discover their strengths and weaknesses. Such a focus on self-leadership skills aligns with principles four and seven of the CCBE Framework and the popular notion of *lifelong-learning* (Leary, 2019) — it is not enough to pass tests or follow course guidelines, lifelong learners should also "learn to learn" and be independent in their learning processes and goals (Gee & Lankshear, 1995).

Teamwork and collaboration with industry leaders and clients were other frequently mentioned positive outcomes of studying at SV: "Being open to having other people's input affects the work and not just running your own show" (P1). The participants agreed that they "understand a lot better how to work with people" (P2) and can transfer this experience to industry and their future careers, showcasing that SV treats teamwork and soft skills as part of the "bundle of skills" (Urciuoli, 2008) expected from a modern worker. Moreover, except for the final project, SV does not allow its students to choose their teams, placing them randomly together. Such a practice received mainly positive feedback from the participants, who acknowledged the importance of working with diverse teams and learning "how to cope with someone else" (P8). This importance resonates with the often-mentioned need for "real-life experience", where a student is "thrown into a quite unstructured team, unclear objectives, and changing plans" (P2), teaching them flexibility and to "roll with the punches" (P2) — all the characteristics that could be described as transferable skills for a chaotic career (Peake & McDowall, 2012) or part of a skills discourses (Urciuoli, 2008).

Finally, participants frequently indicated that the program opened new doors "in unexpected ways" (P1). Thus, some noted becoming more open-minded and less afraid of failure while also feeling "more inclined to listen to new opinions, to read between the lines" (P8). The more pragmatic angle of this discussion highlighted using connections and opportunities to create a "good opportunity to land in something useful" (P14), emphasizing the importance of networking as part of the modern job market.

4.1.2. Challenges: confusing structure, lack of technical training and competent instructors

Despite using diverging metaphors to describing the pitfalls of their learning experience — such as "fraud institute" (P11), "tourist package" (P7), and "a rollercoaster ride" (P3): several common threads in students' accounts prevailed. Some participants complained about the poor structure of the program: "I felt like we were Guinea pigs for something that they didn't even themselves know what they were testing" (P1). A call for a "more clear structure" (P3) was nearly unanimous among participants. The curriculum consisted of modules grouped by themes, and participant feedback on improving the program focused on reorganizing the modules to provide basic skills and understanding "before being thrown into how to solve problems with AI" (P6).

Another primary complaint was the lack of technical skills training. While many participants benefited from soft skill training activities, they expressed dissatisfaction with the amount and quality of technical training provided by the program. Many participants, either completing or having completed their internships, complained that they had to learn all the hard skills on their own. Overall, the uniform feedback about the lack of technical skills showed the participants' concerns with bridging the educational divide between SV and university students who tend to experience a more balanced transition to independent learning from structured guidance.

While several participants mentioned opportunities for self-learning as a positive aspect of the program, some critiqued it, e.g., P14 stated that "there are a lot of tools for self-learning, but there is no good instruction for how to learn". This feedback aligns with the broader critique of HVE, which is characterised by the absence of permanently hired professional teachers, and program managers who often lack industry backgrounds or teaching qualification (Köpsén, 2022a, 2022b, 2024). It also aligns with the broader critique of constructivist approaches in education (Richardson, 2003), which disadvantage students who lack basic skills for effective self-directed learning.

4.1.3. Successful profiles: personal traits, prior knowledge, and social connections

When participants described successful program students, they emphasised certain personality traits, previous background in technology or business, and social connections. Some examples of personality traits/dispositions were: having an "open mind" (P1), "bringing energy or initiatives" (P5), and "taking steps to network" (P9). Students who had either previous technical knowledge or a business background seemed to succeed in SVAI (P4 and P6). As P7 indicated, "they are not as frustrated as me; they already know some of these things, and they were not as tedious as it is for me". Lastly, P14 stressed the importance of social connections in the Swedish job market, both through family and friends. Interestingly, another aspect mentioned only by non-Swedish participants was having a similar cultural background – or, to put it more simply, being a Swede – as the main prerequisite of success in studying, securing an internship position, and having a great career in the future. Thus, according to P14, the most successful people in the program are "the Swedish people, because they already have the connections". This pessimistic remark aligns with our earlier critique of the curriculum and its inability to properly follow the citizenship competences mentioned in the CCBE framework.

4.2. AI knowledge and applications

4.2.1. AI knowledge: demystification, heterogeneity, ethical and societal impacts

Many participants shared that their vision of AI significantly changed during the program. The primary theme was demystifying and operationalising AI. Before the program, some participants perceived AI as a "buzzword", indicating it was something everyone was talking about but not necessarily understanding (P13). As the program progressed, the perception of the subject became clearer. AI transformed into tangible applications they could use and (to some extent) understand. More importantly, the participants began to identify potential business applications for AI technologies, "before the program, AI was way more theoretical and philosophical; people were even talking about it as something you need to conceptualise philosophically to understand. And now, it's more about the business value and how it can change our lives" (P1).

Nevertheless, the level of mastery and understanding of AI technologies after the program was heterogeneous and connected with participants' previous experience and educational background. Several students noted that they had learned to utilise certain AI applications that helped them in their tasks; however, their discussion about AI capabilities remained bounded by these specific tools, indicating a realization of their limited depth in the broader field of AI. They also mentioned a lack of deep expertise: "I

Table 2
AI applications used for work or study as reported by interviewees.

Participant	AI Applications Used
P1	OpenAI API, ChatGPT, OpenAI Vision, GitHub Copilot (coding), Bing Image Creator, ElevenLabs
P2	ChatGPT, Mem.ai, Perplexity, Notion, Coda, etc.
P3	ChatGPT, Zapier, Bing, Figma, Midjourney, Timely
P4	ChatGPT
P5	ChatGPT, occasionally Midjourney and DALL· E 3; also experimented with Kaiber
P6	ChatGPT
P7	ChatGPT
P8	Generative AI of many kinds, automation tools, Copilots for scripting
P9	ChatGPT
P10	Phind, Writesonic, ChatGPT
P11	NLP tools, text-to-video generators, etc.
P12	ChatGPT, Power BI, SQL
P13	ChatGPT, Bard, Copilot, etc.
P14	ChatGPT, Google Bard, Midjourney, Zapier

cannot really say that I'm an expert in anything. I am a beginner" (P10). Another shift in perspective, explicitly mentioned by two of our participants, was connected to understanding the ethical and societal impacts of AI technologies, especially with the risks of applying AI technologies: "I was very, very optimistic in relation to AI. As I've gone through this course, I've understood more of the challenges and the risks with AI" (P9).

4.2.2. AI applications: personal assistant and work-related tasks

In the recruiting survey, participants reported various AI applications they used for work or study purposes. ChatGPT emerged as the dominant application among participants (see Table 2). Several participants demonstrated more exploratory use, employing Midjourney, DALL· E 3, and Kaiber for visual content generation; GitHub Copilot and SQL for programming and data manipulation; and ElevenLabs and text-to-video platforms for media production. Others utilised AI-powered productivity tools such as Notion, Mem, Coda, and Zapier to automate task management. This functional diversity indicates that participants appropriated AI not only for creativity but also for technical execution and workflow optimisation. However, there were notable differences in using AI applications: some participants reported a wide array of tools, while four participants referred only to ChatGPT. These disparities suggest stratified adoption patterns, potentially shaped by participants' technical fluency and familiarity with different AI applications.

During the interviews, participants mentioned several purposes for using AI applications in their personal lives. Firstly, many found that AI applications were useful for ideating and gaining new perspectives. Secondly, AI served as an additional resource for exploring different angles to improve the analysis and presentation of ideas. AI applications functioned as learning aids for some participants to acquire new skills, particularly in areas where they lacked experience. Thirdly, AI applications were used to research and retrieve information, allowing participants to get a thematic overview promptly and then probe further into selected sub-themes. Finally, several participants used AI applications as their personal assistants.

In work contexts, participants described AI as useful for deploying marketing campaigns, programming, text processing, and new business opportunities. For non-native English speakers, AI applications played a useful role in supporting language-related tasks, such as correcting grammar errors and creating presentations. For instance, P14 utilised AI applications to generate articles for their personal website to increase traffic, while P10 used ChatGPT to rephrase their writing and create engaging titles for social media posts. Similarly, P3 applied AI applications during their internship to develop marketing proposals for a company.

The following are further use cases of AI that the participants reported. P1 worked at a startup where AI was used to generate information based on image cues of commercial posters. P4 designed and created an application with AI's support, showcasing AI's capacity for supporting product development. P3, through experimenting with code generated from ChatGPT, learned how to use CAD software from scratch and successfully completed a design task for their internship. Furthermore, some participants viewed AI as an opportunity to launch new business ventures. For instance, P2 developed AI courses for learners aiming to upskill, while P8 led a project at a business consulting company to create an AI use policy for clients adopting AI solutions. However, for some participants, the distinction between using AI for work and personal purposes became increasingly blurred, as P13 explained, "I utilised ChatGPT for everything I did—coding, researching, just about everything".

4.3. Critical reflections on their learning in the SVAI curriculum

4.3.1. Gaps between humans and machines

When participants reflect on "*what is AI for you?*", most summarised AI in terms of instrumental qualities — a set of applications and methods that make life easier and more efficient. However, several participants provided more high-level definitions of AI, focusing on the gap between humans and machines, which they believe will not be bridged in the foreseeable future. For example, AI applications do not inherently exhibit emotions; they merely mimic human connections (P6). Nevertheless, P13 noted that AI sometimes feels more human than other human beings, particularly in terms of empathy and kindness, in P11's case, "ChatGPT is one of my best psychologists". Furthermore, several participants emphasised the lack of security concerns when utilising AI in the workplace, e.g., "the company that I worked with, they had absolutely no understanding about this area. So cybersecurity was not even an issue, and I had to remind them that there are these issues when you upload things" (P13). P10 also worried about the cost of using AI, "Should we really use AI in this project or not? You have to think about the cost". Additionally, participants expressed their concerns about the reliability and consistency of AI-generated content (P1), questioning the capacity of AI to handle large amounts of data (P2). Participants also shared concerns about AI's inability to verify source/reference legitimacy (P8) and the technical limitations of Generative AIs (P12).

4.3.2. Over-reliance and scrutinizing biases

Several participants expressed their concerns about over-reliance on the technologies. Some mentioned that AI biases originated from the datasets supplied by humans; thus, it can represent human mistakes and prejudices. Therefore, when using AI, humans should always critically evaluate their outputs. However, when a user lacks professional skills and prior knowledge of the topic, it may prevent them from spotting the mistakes of AI output. As P2 elaborated: "[AI has] a positive impact on improved efficiency and productivity when an expert uses the AI because they understand what is bad and what is not. But if a novice, like a student who doesn't understand the context or what's relevant and thinks critically about the output, then you will have the opposite effect. Relying on AI when you don't have the expertise is dangerous". Some participants mentioned that they would use better prompts and verify with external resources to scrutinise biases. Furthermore, P1 expressed their worries about *AI reinforcement*: "I'm thinking about is the reinforcement loop of us training AI. The quality of language will decrease. Then we will not be good writers because we're influenced by the same things over and over, and it creates this homogenised language".

4.3.3. Privacy and ethical issues

Several participants believed that many users do not adequately understand important potential consequences of using AI applications, such as privacy and ethical issues. When using AI to generate images or texts, a user's data could be exploited by the company providing the service. There is a risk of entering sensitive information into these systems. Another concern is the potential for intelligent analytics of a user based on the input given to these systems. Participants referred to existing surveillance on social media platforms when elaborating on their concerns about AI. Thus, participants argued that individuals should be cautious about the information they enter and anonymise their inputs when using AI applications. In particular, P6 explicitly raised concerns about "leaking creativity", suggesting that users should avoid inputting creative ideas into these systems, as they might be accessible to others. Additionally, four participants expressed concerns about the systems using large bodies of creative works without recognising copyrights.

4.3.4. Skills, creativity, technological revolution, and the ones "left behind"

While some participants expressed concerns of potential job losses due to AI advancements, they remained optimistic about their own ability to adapt to the job market and some believed AI development would on the whole lead to more job opportunities "[there is a] conversation going on for last couple of years, AI will take people's jobs. It's not true … it will never take your jobs, but rather, it will create more jobs" (P3). On a more critical note, some participants mentioned their worries about AI's potential negative impact on how people think and learn. AI might deprive individuals of chances to better understand how tasks should be done: "I mostly do [my job] by myself because I don't want to stop thinking" (P12); and "if we skip all of that [learning], I think we infantilise ourselves into being just children that want complete automation for things" (P1).

In a similar vein, some participants indicated that generative AI output that partially feeds on itself would not only decrease individual creativity and quality of work, but create a degenerative reinforcement loop. Furthermore, two participants used the expression "technological revolution" to describe societal changes driven by technology, and others described AI in similar disruptive terms, such as "AI is the future" (P9) or as liberating people from boring repetitive tasks (P10). Finally, P13 expressed concerns about the uneven distribution of benefits from technological advancements, particularly highlighting the risks of leaving certain groups behind in the pursuit of progress, "I'm not sad about the whole technology development, but if we forget to think about who will be left behind, and just think about going forward and being advanced then that will make me sad".

4.4. Summary of results

In the end, the participants' appraisals and critiques of the program matched our initial impressions of the SVAI curriculum and its alignment with the CCBE framework. The strengths and weaknesses we identified regarding this alignment were voiced by almost every participant. Overall, both benefits and pitfalls of the SVAI curriculum could be traced back to the school's over-reliance on constructivism (Richardson, 2003) in its educational approach and the overall commodification of modern education that promotes self-optimisation, self-learning, self-responsibilisation, and centres around customer-orientation and market relevance (Ledin & Machin, 2015).

In general, the main volume of critique rested on the lack of tech skills and teaching with limited support for novice learners. As mentioned by the participants, students with different levels of experience in AI and business enter this program at the same time, receive the same training and are unrealistically expected to achieve similar results. The lack of properly trained pedagogical personnel may have led to inconsistent curriculum implementation, with some students left behind. While both self-leadership and ability to work in teams were generally praised by the participants and seen as a prerequisite for future successful employability, most voiced a feeling of being unprepared for their internships and expected disruptive career changes. Overall, the program appeared to be industry-oriented, overshadowing broader citizenship goals such as ethical decision-making and use of AI, as well as cross-cultural communication. While the career-focused competences are undoubtedly well-covered in the program, citizenship competences appear to be barely integrated into learning goals and assessments.

5. Discussion

5.1. AI ambivalence

The cohort as a whole expressed a new kind of ambivalence in the history of work. It is an ambivalence over one's relationship to technology. For example, AI can allow one to be more productive, but it can also steal one's work. So, while you are using AI to draft a business idea, it appropriates the idea as part of its training. AI can make one more autonomous but also less so. One can use AI to create documents, works of art or other artefacts to accomplish tasks that one could not have accomplished without AI, but in the long run, one may come to depend on AI to such an extent that one loses autonomy. AI can help one produce better work, but AI can also ruin one's work, e.g., by generating erroneous text in a document. AI can be a discussion partner, even a psychologist, but AI does not understand emotions; it just behaves as if it does. AI can help one save time, but one has to invest time to keep up with the developments.

The technological ambivalence is different from earlier forms of ambivalence to technology in history in that it is not a simple ambivalence towards technology, such as whether steam engines or highways are a good idea, but simultaneously an ambivalence towards oneself because of how the subjects realise that AI can impact the way they function mentally and how they keep comparing themselves with AI. One way to think about this kind of ambivalence is as bipolar, in which the person vacillates between the positive and negative aspects of oneself as enmeshed with AI (Matthews et al., 2017). We might call this holistic phenomenon *AI bipolarism*.

This vacillation is exacerbated partly because the future of AI is so difficult to predict. At present, it is unclear how AI will develop and what effects it will have on society (Ienca, 2023). Should we put a pause on AI development because of how dangerous the technology is? As we have seen, the students' understanding of what AI is was centred around practical use rather than deeper technological understanding. If you do not understand what AI is, how can you know how you feel about it? For most participants, AI was a black box. Even the ones with a technological background did not attempt to make it perspicuous or indicated that they could do so. AI is a train that the participants jumped on without knowing where it might be heading. There was no choice expressed in the matter because AI is the future. But what if that future is not sustainable? Much of the ambivalence had to do with just how things would work out for the students in the long run. With a more solid understanding of sustainability issues related to AI, it seems reasonable to assume that the students would be able to better take a stand on AI and how they felt about the technology and their future work. After all, AI is a global experiment that no one knows how it will go.

5.2. Human-AI collaboration and the future of work

Previous works have highlighted the numerous areas in which failures to properly assess the results of AI implementation could produce insecure outcomes (Hu et al., 2021). One of the most striking examples of this is AI's systematic ability to suggest insecure code via CoPilot implementations (Negri-Ribalta, Geraud-Stewart, Sergeeva, & Lenzini, 2024; Perry, Srivastava, Kumar, & Boneh, 2023); additional data from the medical domain showed that doctors can over-rely on the results of AI-automated systems and uncritically confirm their decisions (Froomkin, Kerr, & Pineau, 2019). Therefore, an important part of education about AI applicability should be raising awareness of these potential effects. The results of our study show that participants are, in general, aware of the number of security problems associated with the use of external AI tools in the context of organisational practice; however, they do not see themselves as being responsible for advocating for more secure practices, instead, they see little agency in their own actions as future or current AI professionals.

It is understandable that vocational schools focus on the possibilities of technology from a practical or instrumental use perspective. But when it comes to AI, we ought to ask ourselves whether this is sufficient. In our case, we think that a deeper understanding of AI technology and related sustainability issues paired with the employment of permanent teaching personnel could have better supported students in developing a more comfortable relationship with AI and the competences associated with its use. By this, we mean a relation that is not vacillating and uncertain but stable and secure. Furthermore, we may ask, how can we resolve the problems with AI technology and sustainability without such understanding? Ought it not be part of our common understanding of AI in society as far as is feasible? Many of us live in democracies, not in technocracies, and if we wish to continue doing so, we must somehow cater for a sufficient understanding of AI technology in society so that we, as citizens, can make informed decisions about AI in our current and future work. In a technocracy, it is unclear how there could be such a thing as a comfortable relation to AI. This brings us back to the principle of citizenship competences within the CCBE framework. In this study, the SVAI curriculum gave us no indication of fostering student citizenship, neither local nor transnational.

5.3. How sustainable is this approach to AI education?

In general, the practical approach we observed in our case aligns with experts' suggestions about having both core tech skills and transferable/soft skills in AI vocational education (Grover, 2024). However, we found that while the program worked well for soft-skill development, it largely failed to provide a solid foundation for technical skills. In the end, the lack of technical knowledge appears to have contributed to the fact that AI was mostly understood by students from instrumental perspectives (see 4.2.2). As far as we can tell, the program's focus was on how AI could be applied, rather than on the underlying technology and how it actually worked. The focus on application raises the question of how sustainable this approach to education is, given the rapid pace of technological change. How can such a limited knowledge of technology help individuals adapt to these changes and consistently find the best applications for their work?

Interestingly, SV has begun offering an even more accelerated, four-week-long paid program in AI for business in 2025, promising "an immersive, hands-on experience" to help learners navigate the AI landscape, enhance their productivity, and drive innovation at workplace. Based on our findings from SVAI, a much longer program that covers a similar curriculum, we question the effectiveness of this short-term, accelerated, and market-driven format of AI education. Lacking essential technical literacy, it is difficult for trainees to cultivate critical reflection, ethical awareness, and the capacity to engage with the complex and long-term societal challenges posed by rapidly evolving AI technologies. While the acceleration of recent technological changes within AI is tempting education providers to rapidly adopt AI curricula and tools into their programs, we find that the attempts to package AI fundamentals into several weeks of intense education might lead to questionable outcomes.

We observed a technical knowledge gap in the application of AI tools among our interviewees. With limited understanding of how AI functions, novice users often struggle to critically evaluate their outputs (Vaithilingam, Zhang, & Glassman, 2022). They may prioritise efficiency or accept results uncritically, which makes them particularly prone to mistakes. Expert users, by contrast, leverage technical expertise and prior experience (Liu, Xia, Wang, & Zhang, 2023): they test code outputs, verify factual claims, and scrutinise generated content, which enables them to detect hallucinations or flaws (Huang et al., 2025). Several of our interviewees reported using AI for programming tasks, and recent studies underscore some serious concerns. Code generated by large language models (**LLM**s) frequently reproduces vulnerabilities present in their training data, and models trained on publicly available code repositories may inadvertently memorise sensitive information (e.g., credentials, personally identifiable information), potentially exposing users to privacy risks (Chen et al., 2021). Lack of technical knowledge can lead novice users to over-trust AI systems, thereby increasing the risk of misuse.

Furthermore, a limited understanding of the technical aspects, as a result of limited resources allocated to train students in historical and technical AI knowledge, can lead to a narrow perspective on the societal challenges associated with the business innovations generated by the program attendees. The students' main critique of the program was that they did not learn enough about how AI technologies actually worked, leaving them with only a user-level understanding of the technologies. For example, they learned about the possibilities of AI, common security, and ethical concerns (with a focus on LLM-based applications), and how to interact with AI systems through prompt engineering and other techniques. They also learned about the risks associated with AI, such as privacy concerns and intellectual property challenges. However, previous studies have shown that general users share similar concerns (e.g., Mogavi et al. (2024), Yang, Ding, Chen, and Ji (2024)), and it appears that the program did not elevate the conceptual understanding of AI challenges to a more professional level expected from the AI curriculum, as previous works pointed to Long and Magerko (2020), Tenório and Romeike (2023). To balance this critique, we can also add that the program successfully developed communication skills, which provide additional context to the AI skills, as suggested by Hutson and Ceballos (2023).

The program's declared goal was to develop professionals capable of understanding AI well enough to communicate its challenges and opportunities to businesses and "translate" them from the technical domain to organisational decision-makers. Nevertheless, we observed the "communication" component of the curriculum appears to have been effective, but students did not receive sufficient depth of knowledge about the core component—AI. When comparing the examined curriculum with AI education at other levels, such as K-12 curricula, the latter primarily provides a broad overview of AI-related topics and skills (Kim et al., 2021; Liu, Ma, & Li, 2024). However, this approach relies on structured, teacher-led instruction, often incorporating project-based activities under strict supervision (Kim et al., 2021; Liu et al., 2024). Moreover, the primary objective of AI K-12 education is to foster problem-solving skills rather than equip students with practical tools for professional applications.

At the University level, AI-related programs are usually divided into two groups: either to provide the students of non-technical and technical disciplines with some AI tools (e.g. tools for language learning or code development) and general knowledge about AI or to understand the applications of different kinds of AI from a computer science/engineering perspective as a dedicated computer science courses (Southworth et al., 2023). While the former approach is, in general, in line with the SVAI curriculum we examined in the paper, it provides complementary AI knowledge, which should be used as a supporting tool in the student's professional (non-AI-related) activities. Since the declared goal of vocational education is to give a more in-depth and practically helpful understanding of AI practices (e.g., to understand and translate them to non-tech stakeholders on the professional level), it would instead follow the STEM model of AI education with high-profile mathematics and algorithmic courses. However, the results show that the current course model does not fit this educational model, leading to the students' disappointment and doubts about their professional future. In addition, the curriculum faced general challenges of incorporating AI technologies into VET programs (Çela, Vajjhala, Eappen, & Vedishchev, 2025), such as undermining critical thinking and problem-solving skills (Lee et al., 2025), which can lead to overreliance on AI technology.

5.4. Lessons learned

The program's curriculum largely adheres to the CCBE framework (more details are in 2.3); however, based on our interviews, we identified particular issues with principles 6, 7, and 9: students have limited opportunities to reflect on their learning experience, the program does not offer adequate guidance on how to use the provided self-learning tools effectively, and teachers offer minimal support, failing to address their students' personal needs.

Firstly, the enrolment selection criteria at SVAI appear problematic. The selection committee does not differentiate between students with prior technical or business knowledge and those with no experience in either area. Given the students' diverse backgrounds, we recommend either assessing applicants upon entry and tailoring their educational paths to match their experience or addressing any gaps (e.g., giving more in-depth courses on AI fundamentals and business processes to those lacking this knowledge, hiring student assistants for the beginners' programming course), or more strictly specifying the admission criteria, requiring prior education or experience in tech and/or business. As it stands, the current approach seems unproductive for many motivated students without a tech background.

Secondly, the program emphasised self-paced learning, partly due to a lack of competent instructors with AI expertise and a teaching background. This led to participants' frustration as they struggled to acquire technical knowledge on their own. While we are not opposed to self-paced learning, we believe that without tailored instruction and support, it is challenging for students to develop AI competence from scratch. Therefore, we suggest that, at least in certain core disciplines, the education model should shift from self-paced learning to more structured academic teaching, with regular assessments of students' knowledge and the challenges they encounter. This structural change may challenge more profound issues within the HVE model: the absence of permanently employed teachers and inadequate teacher training.

Finally, students appeared to be continuously occupied with one task after another, without opportunities to reflect on their learning journey. Several participants expressed appreciation for our interviews, which gave them a chance to reflect on their SVAI experience. Based on this feedback, we suggest integrating regular reflection sessions – either in groups or with a course advisor – into the program. These sessions would allow students to review their educational progress and discuss any challenges with their advisor and peers if parts of the course are not meeting their expectations. While the school already holds feedback sessions after each module, these are disproportionately focused on group dynamics and instructor performance.

6. Limitation and future work

We acknowledge the following limitations of this case study. First, the participants represent only a portion of the students enrolled in SVAI. While we made efforts to contact as many participants as possible, it is likely that those who responded were primarily students with concerns about the program. In addition, we may not have reached the students who did not check their online communication tool, which could have further limited our findings. Secondly, we did not conduct interviews with industry leaders and other program representatives. Our main motivation was to see the student's perspective on the educational process and compare the promises the program made and fulfilled. Any potential attempts to interview other stakeholders would be complicated by the fact that the program did not have permanent teaching personnel, relying solely on industry leaders without proper pedagogical background; most of the people involved in the educational process did not interact with the students daily and, therefore, did not have the opportunity to observe the educational process.

Another limitation of this study is the generalisability of qualitative research design. However, as Flyvbjerg (2006) reminds us in referring to Kuhn, "a discipline without a large number of thoroughly executed case studies is a discipline without systematic production of exemplars, and that a discipline without exemplars is an ineffective one" (p. 242). That being said, we want to highlight that our alignment with the qualitative framework does not mean a disregard of quantitative methods and bigger samples. We hope this paper will motivate and inform future research into AI curricula in other countries, regions, and education levels, whether through qualitative, quantitative, or mixed-methods approaches. By conducting our case study, we aimed to enrich the exemplars available in the field of AI education research and support others in developing curricula that critically and ethically engage with AI technologies.

Despite the abovementioned limitations, we believe that the results from this case study might be insightful and yield lessons that might apply to European countries that adopt the European Qualification Framework (EQF) to "support cross-border mobility of learners and workers, promote lifelong learning and professional development across Europe" (Europass, n.d.). Moreover, other countries that share a similar weaker apprenticeship model of vocational education (Olofsson & Panican, 2024) can potentially find parallels between our findings and the challenges faced by their VET system. Overall, future research should triangulate the findings from the curriculum documents and students' perspectives with the educators' and/or course coordinators' opinions to provide a holistic overview of the educational practice. Building on the results of this case study, future research can explore comparative case studies across different educational systems to identify patterns and divergences in AI curriculum design, implementation, and learner outcomes. Quantitative studies could complement this study by examining learning outcomes (e.g., improvements in knowledge and critical thinking), students' reflection on their use of AI technologies, or societal and social impact of AI technologies (e.g., sustainability and ethical concerns of AI adaptation), to help establish broader trends and correlations.

7. Conclusion

While there is a consensus on the need to integrate AI into different levels of education, there are few examples of examining AI curricula in vocational education. By analysing an AI curriculum and vocational students' learning experience and reflections, we aimed to understand how AI knowledge can be effectively integrated into vocational education and which factors should be considered with caution while designing such learning programs. Our findings reveal that the program discussed in the case study faces challenges with content organisation and learning guidance, both of which are critical to students' development of technological knowledge. Although the study only took the student's perspective on the curriculum implementation, we believe that the knowledge we received provides some insights into how these types of program should be adapted to fulfil the educational goals and students' expectations and provide a path for future studies, which should also incorporate the educators' perspective on the subject. We recommend creating learning programs tailored to students' profiles, providing more guided instruction in AI technology, and offering students opportunities for reflection throughout their learning journey.

CRediT authorship contribution statement

Anna Metreveli: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Xiaowei Chen:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anders Hedman:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Anastasia Sergeeva:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization.

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Appendix A. Interview protocol

A.1. Information sheet

Description of the Study: This study is part of a research project aimed at studying user perceptions and learning experience of an Artificial Intelligence integrated curriculum. Our main objective is to collect your perspectives on the incorporation of AI into education and its implications for future work. We begin by seeking your general opinions on the role of AI in your learning. Subsequently, we'll probe into your views on the AI applications you employ in your current profession and how AI might influence your working methods. Moreover, we're keen on understanding your overall reflections on the emerging AI trends, particularly concerns about applicability and security. Participating in this study will take approximately 45 min, and you will be compensated with a €15 gift voucher.

Data We Collect: During the interview, we will record your verbal responses. All data will be pseudonymised to ensure privacy. We will maintain a confidential key-list linking your actual names with the pseudonyms. This information is vital for analysing user interactions with contemporary AI educational tools and will greatly inform the creation of future AI-based educational solutions.

Usage of the Collected Data: The data acquired will solely be used for research within the context of this project. It may find its way into academic resources, like journal papers or conference talks, but always in a format that's either anonymised or pseudonymised.

Data Handling Procedures: We will handle your data with the utmost care, storing it under a unique identifier instead of your email. Only the research team will have access to a secure list that connects email to the pseudonym. We'll process your personal data strictly for research and will delete it automatically after 36 months without any intervention on your end. However, the anonymised data, stripped of personal identifiers, will be retained for 48 months.

Your Rights: As detailed on the University of Luxembourg Data Protection webpage, you have the right to access, modify, and delete your data. Participation is wholly voluntary, granting you the freedom to opt-out anytime without offering any justification. You also hold the right to be informed of the study's outcomes.

A.2. Interview questions

Learning experience:

- How did you decide to join this program?
  (If the participants did not mention their motivations, ask more specifically: What are your motives for studying this program?)
- What is your overall experience with the (AI Business Consultant) program?
- How has this program affected your life so far?
- What should be changed in the program to work better for you?
  (Ask them to provide specific improvements, not just the negative sides: "If you are the program manager, how would you improve the program?")
- (*Optional*:) Can you summarise your learning experience from this program?
- How do you apply what you learned from this program?
- What AI can do for you?
- What AI cannot do for you?

Using AI for work:

- (For students:) Have you developed skills that make you more attractive on the job market?
- (For Internship:) What works with these AI applications in your professional life?
  What doesn't work with these AI applications in your professional life?

- (For Internship:) Do any of the clients you have worked for have concerns of privacy or intellectual property concerns related to AI applications?
  (Give an example of privacy concern; for example, by default, your input of ChatGPT will be recorded by Open AI for 30 days to train their model; some users might have concerns about leaking their private information or their intellectual property.)
- How much confidence do you place in AI? – And when it's working, do you feel the need to supervise what it is doing or do you usually take a hands-off approach?
- What drives you to incorporate AI into your work? Can you share some specific motivators?
- (*Optional*:) When you're using AI applications for work, what worries or concerns tend to be on your mind?

Perception and reflection:

- Which people are more successful in this program? (follow up: Why do you think they are more successful?)
- What do you see yourself in three years after this program? (follow up: Has the program changed their career path?)
- (*Optional*:) Can you discuss some of the ways you find AI useful in your daily life or work?
- Thinking back to before you started learning about or using AI, would you say your views of AI have changed over the past few months? If so, how?
- Do you think that relying on AI applications might make us less independent over time? (follow up: Can you explain your perspective on this?)
- What kind of data do you feel is important to keep private from these tools?
- What is AI for you?

Appendix B. Coding scheme

1. Background Info: The participant discusses their job or educational background before joining SV.

Lack of experience in Tech or Business: The participant mentions they did not have previous experience in either technology or business before starting the program.

Business background: The participant mentions that they had training in or work experience with business.

Tech background: The participant's previous work/education was linked to the tech field, information technology, or programming.

2. Learning Experience: The participant mentions their learning experience so far in the SVAI curriculum.

Feedback about SVAI: The participant shares their feedback about the learning curriculum and what could have been done better.

Curriculum component: The participants discusses specifically how the learning module is designed and their opinions on how to improve the curriculum.

Motivations of joining SVAI: The participant mentions their motives or triggers that prompt them to join the SVAI curriculum.

Impact of the program: The participant mentions the impact and influence of the SVAI upon their life or career choices.

Practical implications: The participant mentions the practical parts of applying what they learned from SVAI.

Summary of learning experience: The participant shares their learning experience at the vocational institute, SV.

3. Using AI for work: The participant discusses how they utilise AI tools for work purposes.

Motivations of using AI: The participant shares what drives them to use AI for work purposes.

Advantages: The participant describes what advantages the use of AI brings (What AI can do).

Limitations: The participant elaborates on the cumbersome use cases of AI and the limitations of AI (What AI can not do).

Confidence towards AI: The participant articulates their confidence towards using AI for work purposes.

Concerns or not: The participant mentions whether they have concerns regarding using AI for work (e.g., privacy concerns).

Specific application cases: The participant mentions specific cases where they applied AI tools for work purposes.

Policies at workplace: The participant shares the AI using policy at their workplace.

4. Reflections: The participant shares their opinions, feelings, and perceptions of AI in their private and professional life.

Perception, change or not: Has the participant changed their perceptions of AI in the learning process?

Autonomy or dependency: The participant shares their opinion on Human–AI autonomy or dependency.

AI in my life: The participant shares their opinions on AI's role in their life.

Successful ones: The participant discusses which kind of person was more successful according to their observation.

What is AI for you: The participant's answer to our question "What is AI for you?".

Societal impact: The participant shares their opinion on how AI is shaping the society.

5. Projection: The participant shares their plans of what they will do or are doing after graduating from SVAI.

Future of AI: The participant's projection of the future of AI.

Future plans: The participant discusses their future work or education plans after the program.

References

Acemoglu, D., Autor, D., Hazell, J., & Restrepo, P. (2022). Artificial intelligence and jobs: Evidence from online vacancies. *Journal of Labor Economics*, *40*(S1), S293–S340.

Van den Akker, J., Kuiper, W., Hameyer, U., & van den Akker, J. (2003). Curriculum perspectives: An introduction. *Curriculum Landscapes and Trends*, 1–10.

Alfredo, R., Echeverria, V., Jin, Y., Yan, L., Swiecki, Z., Gašević, D., & Martinez-Maldonado, R. (2024). Human-centred learning analytics and AI in education: A systematic literature review. *Computers and Education: Artificial Intelligence*, Article 100215.

Attwell, G., Bekiaridis, G., Deitmer, L., Perini, M., Roppertz, S., & Tütlys, V. (2020). Artificial intelligence in policies, processes and practices of vocational education and training.

Bewersdorff, A., Zhai, X., Roberts, J., & Nerdel, C. (2023). Myths, mis-and preconceptions of artificial intelligence: A review of the literature. *Computers and Education: Artificial Intelligence*, Article 100143.

Braun, V., & Clarke, V. (2013). Successful qualitative research: A practical guide for beginners.

Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. SAGE Publications.

Capel, T., & Brereton, M. (2023). What is human-centered about human-centered ai? A map of the research landscape. In *Proceedings of the 2023 CHI conference on human factors in computing systems* (pp. 1–23).

Çela, E., Vajjhala, N. R., Eappen, P., & Vedishchev, A. (2025). Artificial intelligence in vocational education and training. In *Transforming vocational education and training using AI* (pp. 1–16). IGI Global Scientific Publishing.

Chen, M., Tworek, J., Jun, H., Yuan, Q., Pinto, H. P. D. O., Kaplan, J., Edwards, H., Burda, Y., Joseph, N., Brockman, G., et al. (2021). Evaluating large language models trained on code. arXiv preprint arXiv:2107.03374.

Chiu, T. K., Meng, H., Chai, C. S., King, I., Wong, S., & Yam, Y. (2021). Creation and evaluation of a pretertiary artificial intelligence (AI) curriculum. *IEEE Transactions on Education*, *65*(1), 30–39.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297–298.

Cournoyer, L., Fournier, G., & Masdonati, J. (2017). Going back-to-school in vocational education and training: Introduction. *International Journal for Research in Vocational Education and Training (IJRVET)*, *4*(3), 196–205.

Crompton, H., & Burke, D. (2023). Artifcial intelligence in higher education: the state of the feld. *International Journal of Educational Technology in Higher Education*, (20), 8.

Europass The European Qualifications Framework (EQF) | Europass, URL https://europass.europa.eu/en/europass-digital-tools/european-qualifications-framework. Accessed January, 10th, 2025.

Felten, E., Raj, M., & Seamans, R. (2021). Occupational, industry, and geographic exposure to artificial intelligence: A novel dataset and its potential uses. *Strategic Management Journal*, *42*(12), 2195–2217.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245.

Froomkin, A. M., Kerr, I., & Pineau, J. (2019). When AIs outperform doctors: Confronting the challenges of a tort-induced over-reliance on machine learning. *Ariz. L. Rev.*, *61*, 33.

Gee, J. P., & Lankshear, C. (1995). The new work order: Critical language awareness and 'fast capitalism'texts. *Discourse: Studies in the Cultural Politics of Education*, *16*(1), 5–19.

Grover, S. (2024). Teaching AI to K-12 learners: Lessons, issues, and guidance. In *Proceedings of the 55th ACM technical symposium on computer science education v. 1* (pp. 422–428).

Guarascio, D., Reljic, J., & Stöllinger, R. (2023). *Artificial Intelligence and Employment: A Look into the Crystal Ball*: *Technical Report*, GLO Discussion Paper.

Hu, Y., Kuang, W., Qin, Z., Li, K., Zhang, J., Gao, Y., Li, W., & Li, K. (2021). Artificial intelligence security: Threats and countermeasures. *ACM Computing Surveys*, *55*(1), 1–36.

Huang, L., Yu, W., Ma, W., Zhong, W., Feng, Z., Wang, H., Chen, Q., Peng, W., Feng, X., Qin, B., et al. (2025). A survey on hallucination in large language models: Principles, taxonomy, challenges, and open questions. *ACM Transactions on Information Systems*, *43*(2), 1–55.

Hutson, J., & Ceballos, J. (2023). Rethinking education in the age of AI: the importance of developing durable skills in the industry 4.0. *Journal of Information Economics*, *1*(2).

Ienca, M. (2023). Don't pause giant AI for the wrong reasons. *Nature Machine Intelligence*, *5*(5), 470–471.

Jovanovic, M., & Campbell, M. (2022). Generative artificial intelligence: Trends and prospects. *Computer*, *55*(10), 107–112.

Kandlhofer, M., Steinbauer, G., Hirschmugl-Gaisch, S., & Huber, P. (2016). Artificial intelligence and computer science in education: From kindergarten to university. In *2016 IEEE frontiers in education conference* (pp. 1–9). IEEE.

Kim, S., Jang, Y., Kim, W., Choi, S., Jung, H., Kim, S., & Kim, H. (2021). Why and what to teach: AI curriculum for elementary school. *vol. 35*, In *Proceedings of the AAAI conference on artificial intelligence* (17), (pp. 15569–15576).

Klarna (2024). Klarna AI assistant handles two-thirds of customer service chats in its first month. URL https://www.klarna.com/international/press. Accessed 14 April 2024.

Köpsén, J. (2022a). Employers placing orders and students as commodities: Swedish post-secondary vocational education and training policy. *Journal of Vocational Education & Training*, *74*(2), 167–186.

Köpsén, J. (2022b). The work of program managers in state-funded employer-driven Swedish higher VET. *International Journal for Research in Vocational Education and Training*, *9*(2), 195–215.

Köpsén, J. (2024). Being successful in the educational market: Employers in practice of Swedish higher VET provision. *Globalisation, Societies and Education*, *22*(2), 240–251.

Laato, S., Vilppu, H., Heimonen, J., Hakkala, A., Björne, J., Farooq, A., Salakoski, T., & Airola, A. (2020). Propagating ai knowledge across university disciplines-the design of a multidisciplinary ai study module. In *2020 IEEE frontiers in education conference* (pp. 1–9). IEEE.

Leary, J. P. (2019). *Keywords: The new language of capitalism*. Haymarket Books.

Ledin, P., & Machin, D. (2015). The semiotics of modernist space in the branding of corporations: A multimodal critical discourse analytic approach. *International Journal of Marketing Semiotics*, *3*, 19–38.

Lee, D., Arnold, M., Srivastava, A., Plastow, K., Strelan, P., Ploeckl, F., Lekkas, D., & Palmer, E. (2024). The impact of generative AI on higher education learning and teaching: A study of educators' perspectives. *Computers and Education: Artificial Intelligence*, Article 100221.

Lee, S. J., & Kwon, K. (2024). A systematic review of AI education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes. *Computers and Education: Artificial Intelligence*, Article 100211.

Lee, H. P., Sarkar, A., Tankelevitch, L., Drosos, I., Rintel, S., Banks, R., & Wilson, N. (2025). The impact of generative AI on critical thinking: Self-reported reductions in cognitive effort and confidence effects from a survey of knowledge workers. In *Proceedings of the 2025 CHI conference on human factors in computing systems* (pp. 1–22).

Lim, S. C. J., & Lee, M. F. (2024). Rethinking education in the era of artificial intelligence (AI): Towards future workforce competitiveness and business success. In *Emerging technologies in business: innovation strategies for competitive advantage* (pp. 151–166). Springer.

Lin, P., & Van Brummelen, J. (2021). Engaging teachers to co-design integrated AI curriculum for K-12 classrooms. In *Proceedings of the 2021 CHI conference on human factors in computing systems* (pp. 1–12).

Liu, J., Ma, J., & Li, S. (2024). Research on school-based AI curriculum design and practice for cultivating computational thinking in high school students. *Education and Information Technologies*, 1–45.

Liu, J., Xia, C. S., Wang, Y., & Zhang, L. (2023). Is your code generated by chatgpt really correct? rigorous evaluation of large language models for code generation. *Advances in Neural Information Processing Systems*, *36*, 21558–21572.

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In *Proceedings of the 2020 CHI conference on human factors in computing systems* (pp. 1–16).

Małgorzata, K., & Shinyoung, J. (2019). OECD reviews of vocational education and training vocational education and training in Sweden.

Matthews, M., Murnane, E., Snyder, J., Guha, S., Chang, P., Doherty, G., & Gay, G. (2017). The double-edged sword: A mixed methods study of the interplay between bipolar disorder and technology use. *Computers in Human Behavior*, *75*, 288–300.

Metreveli, A. (2024). Neoliberal discourse on the webpages of english-medium vocational education schools and coding bootcamps in Sweden. Manuscript submitted for publication.

Misbah, Z., Gulikers, J., Dharma, S., & Mulder, M. (2020). Evaluating competence-based vocational education in Indonesia. *Journal of Vocational Education & Training*, *72*(4), 488–515.

Mogavi, R. H., Deng, C., Kim, J. J., Zhou, P., Kwon, Y. D., Metwally, A. H. S., Tlili, A., Bassanelli, S., Bucchiarone, A., Gujar, S., et al. (2024). ChatGPT in education: A blessing or a curse? A qualitative study exploring early adopters' utilization and perceptions. *Computers in Human Behavior: Artificial Humans*, *2*(1), Article 100027.

MYh (2025). The Swedish qualifications framework—Myndigheten för yrkeshögskolan. URL https://www.myh.se/in-english/seqf. Accessed 10 January 2025.

Negri-Ribalta, C., Geraud-Stewart, R., Sergeeva, A., & Lenzini, G. (2024). A systematic literature review on the impact of AI models on the security of code generation. *Frontiers in Big Data*, *7*, Article 1386720.

OECD (2022). *The landscape of providers of vocational education and training, OECD reviews of vocational education and training*. Paris: OECD Publishing, http://dx.doi.org/10.1787/a3641ff3-en.

Olofsson, J., & Panican, A. (2024). Vocational education in Sweden and youth transitions to working life–challenges and possibilities in the light of a local follow-up study. *Policy Futures in Education*, *22*(4), 475–492.

Ou, A. W., Stöhr, C., & Malmström, H. (2024). Academic communication with AI-powered language tools in higher education: From a post-humanist perspective. *System*, *121*, Article 103225.

Peake, S., & McDowall, A. (2012). Chaotic careers: A narrative analysis of career transition themes and outcomes using chaos theory as a guiding metaphor. *British Journal of Guidance & Counselling*, *40*(4), 395–410.

Perry, N., Srivastava, M., Kumar, D., & Boneh, D. (2023). Do users write more insecure code with AI assistants? In *Proceedings of the 2023 ACM SIGSAC conference on computer and communications security* (pp. 2785–2799).

Richardson, V. (2003). Constructivist pedagogy. *Teachers College Record*, *105*(9), 1623–1640.

Rott, K. J., Lao, L., Petridou, E., & Schmidt-Hertha, B. (2022). Needs and requirements for an additional AI qualification during dual vocational training: Results from studies of apprentices and teachers. *Computers and Education: Artificial Intelligence*, *3*, Article 100102.

Sanusi, I. T., Olaleye, S. A., Agbo, F. J., & Chiu, T. K. (2022). The role of learners' competencies in artificial intelligence education. *Computers and Education: Artificial Intelligence*, *3*, Article 100098.

Southworth, J., Migliaccio, K., Glover, J., Reed, D., McCarty, C., Brendemuhl, J., Thomas, A., et al. (2023). Developing a model for AI across the curriculum: Transforming the higher education landscape via innovation in AI literacy. *Computers and Education: Artificial Intelligence*, *4*, Article 100127.

Statistisk (2024). årsrapport 2024—Myndigheten för yrkeshögskolan. URL https://www.myh.se/publikationer/statistisk-arsrapport-2024. Accessed 10 January 2025.

Sturing, L., Biemans, H. J., Mulder, M., & De Bruijn, E. (2011). The nature of study programs in vocational education: Evaluation of the model for comprehensive competence-based vocational education in the netherlands. *Vocations and Learning*, *4*, 191–210.

Tenório, K., & Romeike, R. (2023). AI competencies for non-computer science students in undergraduate education: Towards a competency framework. In *Proceedings of the 23rd koli calling international conference on computing education research* (pp. 1–12).

Tommasi, F., Perini, M., & Sartori, R. (2022). Multilevel comprehension for labor market inclusion: A qualitative study on experts' perspectives on industry 4.0 competences. *Education + Training*, *64*(2), 177–189.

Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837–851.

Urciuoli, B. (2008). Skills and selves in the new workplace. *American Ethnologist*, *35*(2), 211–228.

Vaithilingam, P., Zhang, T., & Glassman, E. L. (2022). Expectation vs. experience: Evaluating the usability of code generation tools powered by large language models. In *Chi conference on human factors in computing systems extended abstracts* (pp. 1–7).

VERBIsoftware (2024). Maxqda. https://www.maxqda.com/. Accessed 10 Octorber 2024.

Weizenbaum, J. (1976). *Computer power and human reason: From judgment to calculation*. San Francisco: W. H. Freeman and Company.

Wesselink, R., Dekker-Groen, A. M., Biemans, H. J., & Mulder, M. (2010). Using an instrument to analyse competence-based study programs: experiences of teachers in dutch vocational education and training. *Journal of Curriculum Studies*, *42*(6), 813–829.

Yang, X., Ding, J., Chen, H., & Ji, H. (2024). Factors affecting the use of artificial intelligence generated content by subject librarians: A qualitative study. *Heliyon*, *10*(8).

Yrkeshögskolan Hitta utbildning, URL https://www.yrkeshogskolan.se/. Yrkeshögskolan.

Zahilas, L. (2020). The end of eternity: Shaping the future of vocational education and training. *Academia*, (18), 243–265.

Zarifhonarvar, A. (2023). Economics of ChatGPT: A labor market view on the occupational impact of artificial intelligence.

Zhang, C., & Lu, Y. (2021). Study on artificial intelligence: The state of the art and future prospects. *Journal of Industrial Information Integration*, *23*, Article 100224.