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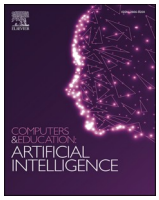

Developing a model for *AI Across the curriculum*: Transforming the higher education landscape via innovation in AI literacy

Jane Southworth [a,1,*], Kati Migliaccio [b,1], Joe Glover [c], Ja'Net Glover [d], David Reed [e], Christopher McCarty [f], Joel Brendemuhl [g], Aaron Thomas [h]

[a] Department of Geography, 3141 Turlington Hall, PO Box 117315, University of Florida, Gainesville, FL, 32611, USA
[b] Department of Agricultural and Biological Engineering, 120 Frazier Rogers Hall, PO Box 110570, University of Florida, Gainesville, FL, 32611, USA
[c] Office of the Provost, 235 Tigert Hall, PO Box 113175, University of Florida, Gainesville, FL, 32611, USA
[d] Career Connections Center, 655 J.W. Reitz Union Drive Suite 1300, PO Box 118507, University of Florida, Gainesville, FL, 32611, USA
[e] Florida Museum of Natural History, 1659 Museum Rd, PO Box 117800, University of Florida, Gainesville, FL, 32611, USA
[f] College of Liberal Arts and Sciences, Bureau of Economic and Business Research, 2014 Turlington Hall, University of Florida, Gainesville, FL, 32611, USA
[g] College of Agricultural and Life Sciences, 2020 McCarty Hall D, PO Box 110270, University of Florida, Gainesville, FL, 32611, USA
[h] UF Information Technology, 720 SW 2nd Avenue, Suite 250 North, Gainesville, FL, 32601, USA

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ABSTRACT

Artificial Intelligence (AI) is a ubiquitous concept and tool already found across society and an integral part of everyday life. As such, basic understanding and knowledge of AI should be a critical component of student education to foster successful global citizens. This position paper describes one possible path to address potential gaps in AI education and integrate AI across the curriculum at a traditional research university. The University of Florida (UF) is infusing AI across the curriculum and developing opportunities for student engagement within identified areas of AI literacy regardless of student discipline. The AI Across the Curriculum initiative being developed at UF will make AI education a cornerstone opportunity for all students. The ultimate goal of AI Across the Curriculum is the creation of an AI-ready workforce covering the essential 21st-century competencies identified as workforce and government needs worldwide. Qualified human capital is essential to face the challenges of the 21st-century, and UF is positioning itself to lead in meeting this global societal need. In designing the AI Across the Curriculum model, all students are provided with a suite of AI opportunities and are encouraged to engage. The university is taking advantage of a significant investment in AI campus-wide to innovate curriculum and create activities that nurture interdisciplinary engagement while ensuring student career readiness. As businesses, industry, and governments transform globally within this AI paradigm shift, AI education, innovation, and literacy will become cornerstones of curriculum with UF providing an inclusive example for all undergraduate, graduate, and professional students. While the AI effort at UF is inclusive and broad, the focus of this paper is on undergraduate programs which also represents a Quality Enhancement Plan (or QEP) effort for reaccreditation of UF's undergraduate programs. This program is highly innovative and transformative, creating interdisciplinary AI literacy opportunity for all students.

1. AI in society

The 21st century has brought with it unprecedented changes in our personal and professional lives. While advances in Artificial Intelligence (AI), which can be broadly understood as computational systems and toolsets which think and act rationally or in some cases like humans (Russell & Noruig, 1995), continue to expand across diverse fields from medicine to medieval literature, higher institutions are in a unique position to expand student competence in and awareness of AI. To stay relevant, higher education must adapt to meet the needs of this rapidly changing world. One area of particular importance is AI literacy (Kandlhofer et al., 2016; Luckin et al., 2022; Ng et al., 2021). AI is no

* Corresponding author.
E-mail addresses: Jsouthwo@ufl.edu (J. Southworth), Klwhite@ufl.edu (K. Migliaccio), jglover@aa.ufl.edu (J. Glover), Janet.Glover@ufl.edu (J. Glover), dlreed@ufl.edu (D. Reed), Ufchris@ufl.edu (C. McCarty), brendj@ufl.edu (J. Brendemuhl), aothomas@ufl.edu (A. Thomas).
[1] Co-lead authors.

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longer just a concept from science fiction; it is increasingly becoming a part of our everyday activities and is changing the way we interact with the world around us (Cantú-Ortiz et al., 2020; Dai et al., 2020). As such, it is crucial that future generations have an accurate understanding of AI and its implications (Zimmerman, 2018). Despite AI expanding within the world-at large, the diffusion of AI across the curriculum for both undergraduates and graduates is sparse and inconsistent outside of the traditional Science, Technology, Engineering, and Math (STEM) fields (Cantú-Ortiz et al., 2020; Dai et al., 2020; Ma & Siau, 2018). In addition, recent educational researchers have argued that AI literacy is a minimum learning outcome for all post-secondary and K12 students (Kandlhofer et al., 2016; Luckin et al., 2022; Ng et al., 2021; Su et al., 2022). Incorporating AI into the curriculum can help to achieve this goal (Dai et al., 2020; Ng et al., 2021; Su et al., 2022). By providing all students with AI learning opportunities, we can empower them with the knowledge and skills needed to thrive in a world that is increasingly shaped by AI. Additionally, AI literacy can help to prepare students for jobs of the future (Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021). As AI becomes more prevalent in the workplace, those who understand and interface with AI will have a distinct advantage over those with less developed AI skills. Integrating AI into higher education is therefore essential for preparing students for the 21st-century workplace (Cantú-Ortiz et al., 2020; Ng et al., 2021).

AI has been used for decades to assist with tasks such as voice recognition, handwriting analysis, image recognition, and natural language processing. AI is also becoming ubiquitous across society, from self-driving cars to smart homes and voice assistants; AI is changing how we interact with the world around us (Cantú-Ortiz et al., 2020; Hu et al., 2019; Ng et al., 2021). This means that AI is not something that will happen in the future but rather something that we are living through today (Cantú-Ortiz et al., 2020; Dai et al., 2020; Hu et al., 2019; Kandlhofer et al., 2016; Luckin et al., 2022). One study showed that only 33% of consumers surveyed claimed to have used AI for a specific task, which is shockingly low given that already 77% of devices we use feature some form of AI (PEGA, 2022). The most common of these tasks were making purchases, searching for information, and conducting research. The technological development of AI has had a significant impact on our society in work, education, and other aspects of daily life. Though there are many opinions about the implications of AI for society now and in the future, one thing is certain: AI's presence cannot be ignored (Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016; Ng et al., 2021). Our society is more digitalized and automated than ever before. We will have to understand what AI is, and how it works to succeed in this new digital paradigm.

AI is defined in diverse ways, as there often is a discipline or industry perspective or application for which a particular definition is derived. For our purposes in this paper, AI refers broadly to include related expertise and disciplines when used with AI (e.g., such as statistics and data science). This broad definition is comprehensive of all AI applications and fits the interdisciplinary nature of our *AI Across the Curriculum* model. Thoughtful incorporation of AI into a curriculum is one approach for providing AI knowledge and skills to the next generation (Ng et al., 2021). With a better understanding of what AI is and how it can be used, we can provide students with knowledge and skills that are needed for the 21st century (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Dai et al., 2020; Luckin et al., 2022; Markauskaite et al., 2022; St Louis et al., 2021; Su et al., 2022). To meet this goal, higher education needs to integrate theories and applications of AI across the curriculum and disciplines and not consider it as an 'add on' requirement that becomes a check box instead of an essential element to the curriculum. UF's new model was designed to create a curriculum for students to succeed in acquiring their AI knowledge and skills related to identified AI literacy topics.

The next generation of students requires competency in AI literacy to recast a new societal norm embracing AI and integrating it into daily tasks. Additionally, students need competency to interpret AI for success in their personal and professional lives (Kandlhofer et al., 2016; Ng et al., 2021). Learning about AI can provide students with insight into new career paths as well as potential mentors to further develop their credentials and workforce readiness. Thus, the AI literacy model we propose encourages interdisciplinary engagement further expanding student experiences and career readiness skills (Zimmerman, 2018). Although this paper focuses on the curriculum and academic scholarship of higher education, the AI curriculum at UF, as well as other universities, does not exist independently from university research. Research activities are often integrated with teaching activities and each benefits from the other. The investment of universities in research to remain innovative and relevant in the technological race contributes to the quality of student learning and its ability to create translational career skills. AI is already being used in many different disciplines, and there is no question that it will be part of students' lives. Thus, greater AI competency in students will provide them with a greater potential for achievement (Borenstein & Howard, 2021; Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021).

2. Identifying the GAP - Why do we need AI education?

The technological innovations of the 21st century have created a world that fundamentally operates differently. These innovations have also generated new expertise and workforce needs that did not previously exist (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016; St Louis et al., 2021). Some have referred to this as the Fourth Industrial Revolution and have identified the impact of these innovations on how we live and work (Ahmad, 2019; Ng et al., 2021). For example, the World Economic Forum (2022) described the Fourth Industrial Revolution as "merging the physical, digital, and biological worlds and fusing technologies in ways that create both promise and peril." Additionally, the Forum highlighted the need to integrate ethics when developing and using new innovations. This includes engaging public and private sectors to create recommendations for policies that embrace ethical practices in innovation and thus increase the benefits of AI innovations more broadly. The Forum also identified AI as a cross-disciplinary concept and as an intricate and developing component of our world in the 21st century (World Economic Forum, 2022). Likewise, governments have recognized the AI expertise needed to ensure future growth and stability. The 2021 National Security Commission on Artificial Intelligence (NSCAI) Final Report noted that "big decisions need to be made now to accelerate AI innovation to benefit the United States and to defend against the malign uses of AI." The report also identifies human talent in AI-enabled technology as the greatest barrier for the United States national security sector. The report further outlines the need to develop a digitally literate workforce with AI readiness by 2025 (NSCAI, 2021).

Not only has there been global and government recognition of AI as a topic to be explored across disciplines, the National Academies of Sciences, Engineering, and Medicine (NASEM) published a report titled "Data Science for Undergraduates: Opportunities and Options". This report outlined the importance for students of all backgrounds, disciplines, and professional goals to have the opportunity to learn data science. They identify different elements of data science including "the availability to understand data, making good judgements about and good decisions with data, and using data analysis tools responsibly and effectively" (NASEM, 2018, p. 138). Data science has an important role with AI. The two topics are often used together given that data science is the first step to creating or implementing AI methods, and the limitations or biases present in data will appear in the AI created solution (Borenstein & Howard, 2021; Long & Megerko, 2020). The acknowledged need by the NASEM (2018, p. 138) for all students to have this opportunity further emphasizes the necessity to educate and provide experiences across disciplines instead of focusing on a narrow subset of students having the opportunity to learn about data science. In a similar fashion, universities and colleges have embraced the importance of

speaking and communication skills across all disciplines. Thus, precedent exists where a topic or skill has been shown to have broad need and therefore was integrated across college and university campus disciplines to benefit students and future employers (Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016; St Louis et al., 2021). For our purposes, we consider AI to be inclusive of related data science.

Higher educational systems in the United States have evolved to prepare students to enter the workforce as a primary mission. As such, colleges and universities continually adapt the curriculum to align with employer needs (Ahmad, 2019; Cantú-Ortiz et al., 2020; St Louis et al., 2021). One need clearly identified globally, and also specifically in the United States, is for individuals entering the workforce with greater AI knowledge and skills to meet 21st-century challenges (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016). The NSCAI Report (2021), along with the NASEM report (2018) and the World Economic Forum (2022), all provide a consistent mandate for modifying university curricula to meet the knowledge and skills workforce needs.

3. AI in higher education

The infusion of AI across so many aspects of human life has created a need for us to not only be able to use AI (even when we do not realize it) but to also have a greater understanding of its broad applications, usefulness, limitations, and biases. Thus, there is a need for a concerted effort to educate across all sectors to create a population better prepared to thrive in our rapidly evolving AI-enabled world (Cantú-Ortiz et al., 2020; Dai et al., 2020; Zimmerman, 2018). Even as some AI specialists openly speculate that a fundamental understanding of AI is not necessary (Lee, 2017), we believe it is critical to provide everyone with fundamental knowledge related to AI and its diverse and ever-increasing applications (Borenstein & Howard, 2021; Dai et al., 2020; Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021). This includes creating greater opportunities for scientists, engineers, medical professionals, and everyone who deals with data and information to understand the basics of machine learning, deep learning, and the various AI techniques that are impacting our lives. Note, we are not suggesting that every student needs to have a Ph.D. in AI or machine learning. We are, however, suggesting that there is a need for greater education across the spectrum of societal needs (Ng et al., 2021). It is particularly the responsibility of educators – who are generally reflective practitioners – to understand the ramifications of implementing AI in the educational system and to take active steps to prepare students for their roles as stakeholders and citizens in a world defined by the interaction of technologies (Zimmerman, 2018).

To date, the incorporation of AI within the curriculum has been restricted to certain STEM disciplines and fields, such as data science, computer science, and engineering (Cantú-Ortiz et al., 2020; Kandlhofer et al., 2016). While these are important disciplines and are clearly those where programming and AI development expertise often reside, it has also become apparent that there is a critical need for broader AI education campus-wide (Ng et al., 2021). Looking at existing programs in AI education, institutions of higher education currently have very limited campus-wide AI initiatives. AI is not simply a set of tools that can be considered in isolation, as technologies often are. AI, instead, is a comprehensive set of skills or approaches for transdisciplinary inquiry, and it encompasses, or should encompass, the full life experience and education of a learner. AI should be built into the fundamental curriculum goals of a university. Some programs have embraced this cross-disciplinary idea such as University of California, San Diego, the University of Washington, and the University of California, Berkeley. However, a considerable lack of depth and breadth still exists when it comes to AI education, which is a critical issue since AI is not simply a computational discipline. Rather, AI is a pedagogical challenge as it represents a broad array of fundamental skills and approaches, as well as significant and important questions of ethics and bias, and as such, should be an important part of any quality higher education curriculum (Cantú-Ortiz et al., 2020; Ng et al., 2021).

To consider how *AI Across the Curriculum* initiatives could be developed, we can learn from K-12 curricula which have some experience incorporating the rapid expansion of technology, and specifically AI, into education (Chiu & Chai, 2020; Kandlhofer et al., 2016; Xia et al., 2022). This formal incorporation of AI into the K-12 curricula has been occurring both nationally and internationally. United States entities including Google for Education, Microsoft K-12 Education Transformation Framework, the National Science Foundation, and a whole suite of computer-based special interest and education groups have been part of the development and call for technology integration in K-12 student curricula. This process is ongoing, and while they are currently at the beginning stages of developing such programs, institutions of higher education can certainly learn from these guidelines, curricula, tools, and resources (Lee et al., 2021).

The movement to incorporate AI in education has arisen in various countries in recent years (Cantú-Ortiz et al., 2020). For example, in 2017, China's State Council announced its intention to include an AI curriculum in primary and secondary education and set the goal of becoming a world leader in AI by 2030. In 2018, AI was officially introduced into the curriculum by the Education Ministry, and the first AI textbook was utilized (Chiu & Chai, 2020; Dai et al., 2020; Su et al., 2022). Singapore has developed AI education opportunities for both teachers and students, with the creation of two AI programs: "AI for Students" which looks at facilitating AI formal and informal learning for secondary school students, and the "AI for Kids" (AI4K) program, which trains both schoolteachers and parents to become AI Bootcamp instructors for primary students. At the same time, in 2018 the government announced "AI Singapore" to develop students' capabilities in AI (Su et al., 2022). Likewise, programs in K-12 in Hong Kong, Japan, and Korea were developed from 2017 to 2019, all aimed at incorporating AI education into school curricula, although some of these are focused more on technology skills and development, more than a holistic understanding of AI (Xia et al., 2022). In 2020, the European Union developed a white paper on "Artificial Intelligence—a European approach to excellence and trust" and now plans to incorporate AI at all levels of education. However, even with all these national-level developments, there is still a lack of consistent approaches or even agreement on AI curricula and content to be covered (Chiu & Chai, 2020; Dai et al., 2020; Kandlhofer et al., 2016; Ng et al., 2021; Su et al., 2022; Xia et al., 2022).

There are currently a few university-level resources that represent a more comprehensive approach to incorporating AI into the curriculum. Stanford University launched a new institute for Human Centered Artificial Intelligence (HAI, announced in 2019). Their institute includes building partnerships with a wide range of entities with a goal of a better future for humanity through AI and a specific focus on becoming an interdisciplinary global hub for AI (https://hai.stanford.edu/). Likewise, Northwestern University focuses on curriculum availability for educating university students and workforce professionals on AI theory, practice, and impact (https://ai.northwestern.edu/education/index.html). However, these programs are found only in their computer science and electrical and computer engineering departments. Other universities such as Harvard, Massachusetts Institute of Technology, and Carnegie Mellon have created courses or programs that are centered around the study of the ethics and implications of AI. All of these initiatives, whether at lower school (or elementary), upper school (middle and high schools), or within select programs and higher education, lead us to ask 'What are the most effective and useful programs that infuse AI concepts across a curriculum and within all disciplines within higher education?' From a simple review of the literature and the ubiquitous nature of AI already within society, evidence shows we are at a critical moment in which we must educate all students with basic concepts and knowledge of AI. How then will institutions of higher education build AI curricula ready to face the challenges of the 21st-century and ensure our

students graduate with the knowledge and skills to not only survive but thrive in the 21st-century workplace? (Ahmad, 2019; Borenstein & Howard, 2021; Cantú-Ortiz et al., 2020; Dai et al., 2020; Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021; St Louis et al., 2021). The lack of comparable case studies at other institutions in the United States or more globally, highlights the relevancy and timeliness of this academically inclusive model of AI Across the Curriculum. While this program is currently in development and implementation at UF, future evaluation and assessment of the model outcomes and goals will be of critical importance. Laupichler et al. (2022) reported on 30 studies (from 902 initial records) describing how AI literacy was being taught in higher and adult education. They found the research to be in its infancy and identified the need for refinement of concepts and materials. In addition, none of these reviewed studies portrayed campus wide initiatives, again highlighting the novelty of this position paper presentation and current lack of comparable case-studies for this model of *AI Across the Curriculum* instituted at a major university of higher education.

This then is the goal of UFs *AI Across the Curriculum* initiative. The University has already invested in AI development and engagement across campus, built a world-class faculty well-versed in the concepts, and assembled a technical staff of AI specialists to assist faculty and students in using the latest AI supercomputer. The educators are forward-thinking visionaries who are creating a curriculum for the 21st-century. UF will enable students to be ready for that future and engage with it. An investment has been made in the fundamentals that are necessary to infuse AI across all disciplines and to build a curriculum that will empower students to be at the forefront of the wave of technology.

4. AI across the curriculum at UF

4.1. UF investment in AI

The University of Florida with support from NVIDIA recently launched higher education's eighth most powerful supercomputer and the 22nd most powerful system in the world, which represents a complete transformation for computational abilities and opportunities campus wide (Merrit, 2021). The supercomputer, called HiPerGator, is a room-sized supercomputer that draws 1.1 MW at full capacity. HiPerGator is built with 291,024 cores using 148 NVIDIA DGX systems and 1120 NVIDIA A100 processors which are optimized for AI operations. When processing, HiPerGator chews through calculations peaking at 21, 314.7 teraflops/second. It is this investment which spurred the initiative to develop *AI Across the Curriculum* at UF, and while researchers must pay for its use on funded projects, the resource is freely available for instructional and pedagogical purposes.

NVIDIA's Cheryl Martin sees a future where AI-ready employees will be crucial to the workforce; and thus, NVIDIA contributed UF's supercomputer to support this outcome. She also recognizes opportunities for rethinking jobs through technological change–creating new tools or training people in skills needed by 21st-century industries, but which currently have not been integrated into campus-wide curricula. With the help of NVIDIA, students and faculty at UF can access a supercomputer for research or teaching. This is an exciting development in education because it not only provides access to powerful computer hardware but also creates a skilled workforce trained on how to best use such technology.

UF is unique given the breadth of disciplines and expertise available at the state's premier Land-Grant institution, with hundreds of faculty members already using AI in their research and teaching programs. UF's faculty was recently expanded with the addition of over 100 newly hired, AI-focused faculty to increase the university's AI teaching and research capacity and to prepare thousands of students annually to enter society equipped for success. University Provost, Dr. Joseph Glover believes this to be a transformational initiative given the resource investment and the many opportunities available through these technologies. Based on these investments in AI, the greater goal then becomes how to bring *AI Across the Curriculum* to fruition in terms of pedagogy, curricular design, and program development, so that all interested UF students can engage in AI and to revolutionize our institution and our future.

This obvious need (as outlined previously from global, government, and academy reports) for a shift in our programs to integrate cross-cutting pedagogy focused on AI was noted by UF leadership in the UF 2020 and 2021 Accountability Plans (University of Florida 2020 Accountability Plan, ; University of Florida 2021 Accountability Plan,). The plans outline the need for a focus on AI to provide a growing future economy for Florida, to allow the university to become a national leader in AI, and to provide increased opportunities for our students. UF made AI the centerpiece of a major, long-term initiative that combines world-class research infrastructure, cutting-edge research, and a transformational approach to curriculum. The University's AI efforts were further supported by investment from private and corporate philanthropy, the launch of a new supercomputer (previously described), and over 100 new faculty hires across all 16 colleges (Fig. 1) with more hiring still underway. The UF Provost also recognized the need for centralized leadership of such a bold academic effort and established the Artificial Intelligence Academic Initiative (AI^2) Center in 2022. This AI^2 Center provides leadership and organization for the UF AI curriculum and other AI-related academic activities across campus.

4.2. AI pedagogy

AI pedagogy refers to the methods and strategies used to teach artificial intelligence (AI) to students. It encompasses not only technical skills related to AI programming and algorithms, but also the broader concepts and principles of AI, such as machine learning, natural language processing, and robotics. One important aspect of AI pedagogy is the emphasis on hands-on, experiential learning. This can include working on projects that apply AI techniques to real-world problems, participating in hackathons or coding competitions, and engaging with open-source AI communities. These activities not only help students learn technical skills, but also foster creativity, critical thinking, and problem-solving skills that are essential for success in the field of AI.

AI literacy, on the other hand, which was first coined as a term in 2015 by KonishiY (2015), refers to the knowledge and understanding of AI that is necessary for individuals to participate in the broader discourse around AI and make informed decisions about its use and implications (Laupichler et al., 2022). This includes an understanding of the capabilities and limitations of AI, as well as its potential impact on society and the ethical considerations involved in its development and deployment. Developing AI literacy is important for a number of reasons, most already discussed above. For one, AI is increasingly being integrated into various aspects of our lives, from self-driving cars to virtual assistants, and technology users should have the knowledge and understanding to make informed decisions about the use of these innovations (Lee et al., 2021). In addition, as AI continues to advance, it will likely have a significant impact on the job market and the nature of work, and thus, our students benefit when graduating with the knowledge and skills to adapt and thrive in this changing landscape (Laupichler et al., 2022). In a review by Laupichler et al. (2022) the authors note that research on AI literacy is still very young and as such there is little literature available on this topic. Li (2021) discusses how definitions of AI literacy are currently lacking. Again, this highlights the necessity for building a strong model of AI literacy within higher education, that is potentially transformative of how we incorporate AI pedagogy across the curriculum. It also serves to highlight the importance of future assessment and reporting on UF's *AI Across the Curriculum* initiative in terms of its successes and failures as a program focused on addressing AI literacy needs campus wide.

The pedagogy of teaching at universities has developed to refine

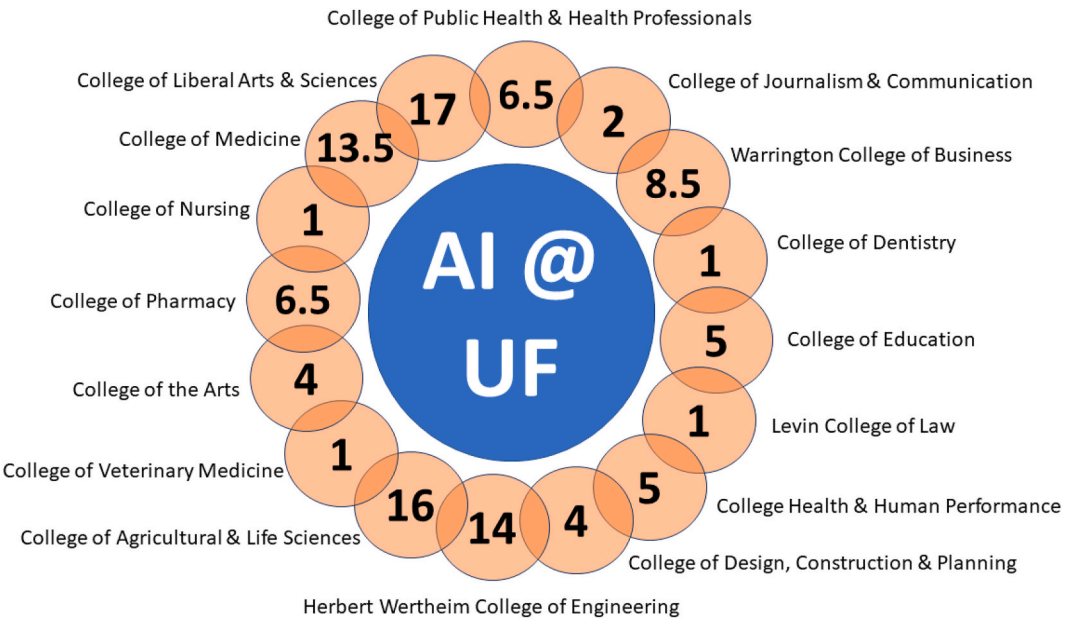

Fig. 1. AI Faculty Hiring Initiative – the college locations of the 106 faculty hired as part of the AI faculty initiative 2020–22, an ongoing process, with another 2 faculty in the Libraries and Florida Museum, and more hires currently underway. [Note 0.5 faculty indicates faculty in joint appointments across different colleges.].

knowledge and skills with focus on a topic or degree, such as engineering, geography, medicine, or economics. While this method is useful in many regards, limitations to this approach are evident; specifically, this approach lacks engagement of students across interdisciplinary teams more reflective of a workplace environment, lacks engagement of students with industry partners, and lacks exposure of students to time-sensitive, real-world challenges. The curriculum can be improved by identifying a mechanism to link disciplines and address these limitations. AI offers a timely and relevant mechanism to bridge this gap. Not only does AI provide this unique opportunity for transformative pedagogy, but there is a global and national need for a workforce trained in AI. The problems society faces are truly complex, and viable solutions often depend on integration of domain expertise with powerful tools such as those found in AI. However, our current education system often does not recognize that these solutions require convergent thinking.

The AI^2 Center is the central organizational point at UF for AI-related academic programs, and thus, it is also the entity that is responsible for the implementation of the 2024 Quality Enhancement Plan (QEP), titled *AI Across the Curriculum*, which is required by the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC) accreditation every 10 years. The undergraduate-focused QEP requires key elements, including topic identification through a comprehensive process, broad base support from institutional constituencies, focus on improving specific student learning outcomes and/or student success, the commitment of resources from the institution, and assessment methods which are evaluated through the duration of the program. This development of the UF comprehensive plan began in 2021 with the establishment of a task force. The UF Provost Office charged two co-chairs (authors Jane Southworth and Kati Migliaccio) and a diverse committee from across the university community, with the task of developing a QEP with a topic focus on *AI Across the Curriculum*. Given the QEP necessity for undergraduate program accreditation and the AI-related resources available, an opportunity was presented to consider a QEP plan that not only focused on a theme but also integrated pedagogical changes to better serve our students and prepare them for the 21st-century professional workforce. The new pedagogy model we propose was derived from activities required for the QEP and the ongoing AI based initiative across campus.

4.3. UF AI literacy model

In higher education, AI is currently used to enhance the learning experience and improve student outcomes and is collectively referred to as Artificial Intelligence in Education (AIED). There are several approaches to using AI in higher education, including using AI to personalize learning, facilitate communication, and enhance assessment (Chen et al., 2020; Hwang et al., 2020). AI can be used to create customized learning experiences based on the individual needs and abilities of each student. This can be accomplished through adaptive learning algorithms, which adjust the content and pace of the learning material based on the student's progress. Personalized learning can help students stay engaged in the material, leading to better outcomes. Another approach to using AI in higher education is to facilitate communication. AI can be used to create virtual assistants or chatbots that help students communicate with their instructors and classmates. These assistants provide support and answer questions, freeing up instructors to focus on more complex tasks. AI can also be used to create virtual reality environments where students practice skills and interact with others in a simulated setting. Finally, AI can also be used to enhance assessment in higher education. AI algorithms can be used to grade essays and other written assignments, freeing up instructors to focus on providing feedback and helping students improve. Likewise, AI can assist in creating adaptive tests that adjust the difficulty of the questions based on the student's progress, allowing for more accurate assessment of their knowledge. More recently, the metaverse concept (think of a fully or partially virtual world where social activities such as discussions, collaborations, games etc. can occur) has been introduced to expand the use of AIED and it is expected that more research and case studies related to such metaverse-based education will be reported in the future (Hwang & Chien, 2022). Overall, AI has the potential to significantly improve the learning experience in higher education. By personalizing learning, facilitating communication, and enhancing assessment, AI can help students learn more effectively and achieve better outcomes. While AIED has been established as a field for over 30 years, this paper deals with a different emphasis of AI in Education – that of training students and our future workforce in AI pedagogy such that graduating students are AI literate.

AI literacy is the ability to understand, use, evaluate, and ethically navigate AI (Long & Megerko, 2020; Laupichler et al., 2022). There are

four key areas of AI literacy. 1) Knowing and understanding AI involves understanding the basics of what AI is and how it works. This includes knowledge of machine learning algorithms, the data that is used to train them, and the limitations and biases that can be present in AI systems. 2) Using and applying AI involves the ability to use AI tools and platforms to solve problems and accomplish tasks. This may involve coding and programming skills, as well as the ability to understand and work with large datasets. 3) Evaluating and creating AI involves the ability to assess the quality and reliability of AI systems, as well as the ability to design and build AI systems that are ethical and fair. This requires a deep understanding of the technical aspects of AI as well as an understanding of the social and ethical implications of AI. 4) AI ethics involves understanding the moral and ethical implications of AI and being able to make informed decisions about the use of AI in various contexts. This includes considerations of fairness, transparency, accountability, and the potential impacts of AI on society and individuals. Overall, being literate in AI requires a combination of technical knowledge and understanding of the social and ethical implications of AI (Yi, 2021). Individuals and society as a whole benefit from being aware of the capabilities and limitations of AI which allows for responsible and ethical use (Borenstein & Howard, 2021; Dai et al., 2020; Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021; Zimmerman, 2018).

The foundation of the UF model is based on these four AI literacies as outlined in the previous paragraph and discussed in more detail by Ng et al. (2021). A fifth category, "Enabling AI", was also identified to capture academic courses that support AI through related knowledge and skill development (e.g., programming, statistics) and/or contain a lower total AI content of one of the four Core AI literacy topics. Each of these categories contains a variety of knowledge and skills that students can learn through different types of experiences (Fig. 2). For example, students might learn about AI through reading texts, watching videos, or attending lectures. Alternatively, students might learn about AI through hands-on experiences, such as coding projects or data analysis. The UF model is designed to first clarify the different AI literacies presented in different academic activities (Dai et al., 2020; Kandlhofer et al., 2016; Long & Megerko, 2020; Ng et al., 2021). This allows students to build their expertise by selecting courses focused on literacies of their interest. Second, the UF model provides students with identified AI literacies by course that can be packaged to showcase student AI skills and 21st century competencies (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Ng et al., 2021). Lastly, the course AI identification approach allows review of course offerings to identify gaps or needs to ensure AI learning opportunities are available for all undergraduate students.

To focus the plan on student learning and the conditions that enhance student learning, these five AI categories were identified to be developed and assessed (Long & Megerko, 2020). These concepts were validated in the literature (Ng et al., 2021) and matched to the goals of the *AI Across the Curriculum* QEP (Fig. 2). The QEP task force identified a need to develop a process to evaluate courses faculty considered as 'AI' in a consistent manner and to designate each as a particular AI category. This process would help students determine which AI literacy competencies they would gain from each course, allow the AI^2 Center to ensure classes identified as AI met the expected criteria, and assist with tracking the competencies taught. The course AI identification process is managed via an AI curriculum subcommittee, within the process of

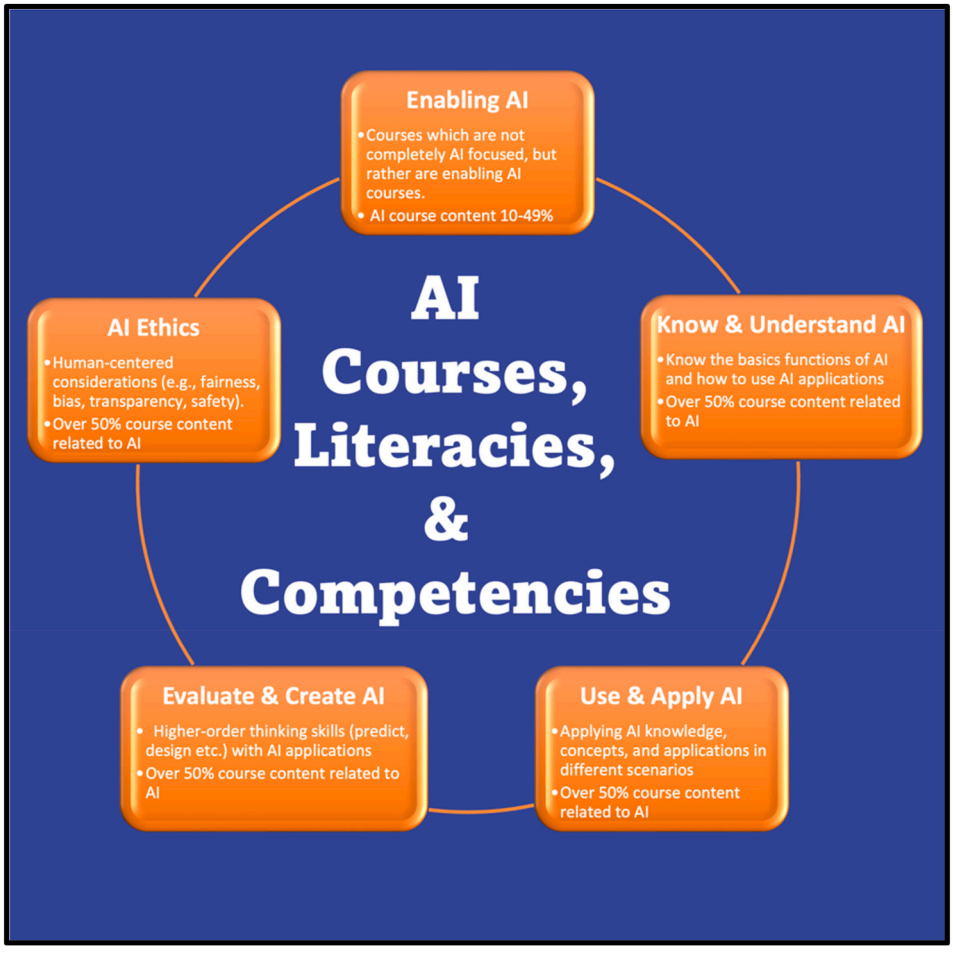

Fig. 2. UF model of AI course literacy categories linked to competencies within the AI Across the Curriculum Initiative. AI Literacy types based on the model from Ng et al., 2021.

existing undergraduate and graduate curriculum committee review at UF, similar to how General Education courses are reviewed. UF's AI curriculum subcommittee reviews, evaluates, and identifies the AI knowledge and skills within the course. This course identification began by reviewing almost 230 existing AI related courses, and then evaluating new courses as they are submitted to the university curriculum committee.

To focus the plan on student learning and the conditions that enhance student learning, the Student Learning Outcomes (SLOs) for each of the five AI literacy types are identified. The State of Florida Board of Governors has mandated that all baccalaureate degree programs in the state public universities develop Academic Learning Compacts (ALCs) that include SLOs in three areas: content knowledge, critical thinking, and communication. SLOs were developed to align with these goals and be measurable (Fig. 2, Table 1).

The UF AI Literacy Model is integrated into the different AI initiatives as a foundational component across the curriculum. This foundational model can be seen in the four initiatives identified for implementing the *AI Across the Curriculum* QEP including 1) curriculum development, 2) academic programs and pathways, 3) AI undergraduate scholars and AI undergraduate medallion programs, and 4) AI career development and industry engagement. While these initiatives were designed for the undergraduate-focused QEP, their implementation is relevant across all of campus. Specific initiatives are outlined below with key elements.

4.3.1. Curriculum development

The QEP curriculum development initiative includes both creating new AI course content and identifying AI literacy categories present in both existing and newly developed academic courses. Both activities are managed by the AI^2 Center. The AI^2 Center leads the new Undergraduate Curriculum Committee (UCC) subcommittee specifically assigned to review AI courses and to identify the AI literacy categories within them. The subcommittee is composed of faculty from across campus, with AI and curriculum development experience and assigned by the AI^2 Center Director with assistance from the colleges. The AI^2 Center also uses information on the AI courses evaluated to assess the prevalence of different AI literacy topics in the curriculum (Ng et al., 2021). Guidelines on course literacy identification were developed by the subcommittee and continue to be adapted with oversight by the AI^2 Center. The AI^2 Center supports new AI content development in courses through seed grants. Additionally, the course development seed grants can fund pairing faculty (i.e., novice with AI mentor/expert) to team teach and develop materials for innovative courses. Seed funds to create new courses and course content ensures that AI courses are widely available across the university and that all AI literacy areas are represented across campus.

4.3.2. Academic programs and pathways

The QEP academic programs and pathways (e.g., certificates, minors, majors, tracks) initiative includes programs from across the university on a variety of topics and at a variety of knowledge levels – from novice to expert. The academic programs and pathways are catalogued for students to find easily and are advertised and managed though the AI^2 Center, taking advantage of the established www.ai.ufl.edu website.

UF's certificates, minors, and majors exist within the university's sixteen colleges. However, UF introduced for the first time a certificate that spans the entire university. The AI Fundamentals and Applications Certificate is available to any UF undergraduate regardless of their major. This certificate was established to provide rapid access for thousands of students across the university to an official certificate registered on their transcript. The certificate has two required courses 1) EEL 3872: Fundamentals of Artificial Intelligence (taught in the College of Engineering) and 2) PHI 3681: Ethics, Data, and Technology (taught in the College of Liberal Arts and Sciences). For the third course, students select from a suite of courses offered by various colleges – so it can be more relevant to their discipline of interest e.g., BME 4760 Biomedical Data Science (EG-BME major) or in Business: QMB 3302 Foundations of Business Analytics and Artificial Intelligence. This university-wide certificate allows colleges and departments to offer formal AI training to their students after the development of a single AI application course, thus reducing the barrier to entry for all colleges. This 'AI Fundamentals and Applications' Certificate is therefore intended for undergraduates of all majors (both technical and non-technical) to learn the fundamentals of AI, its applications to real-world problems in various disciplines, and ethical and professional responsibilities of these technologies. This provides for acquisition of AI skills, but still allows individualization of coursework for students, based on interests and background. In addition to these very broad, introductory certificate programs, UF also has a suite of specialized AI-related certificates, and

Table 1
The UF AI Literacy Model: Descriptions for the five AI categories, content, and related student learning outcomes. AI Literacy types based on the model from Ng et al., 2021.

AI Literacy categories	Description	AI content[a]	SLOs
Enabling AI	Support AI through related knowledge and skill development (e.g., programming, statistics) and/or contain a lower total AI content of one of the four Core AI Literacy topics.	10–49%	SLO1. Identify, describe, and explain the components, requirements, and/or characteristics of AI. (Content knowledge and communication) SLO2. Recognize, identify, describe, define and/or explain applications of AI in multiple domains. (Critical thinking and communication)
Know & Understand AI	Know the basic functions of AI and to use AI applications	>50%	SLO1. Identify, describe, and explain the components, requirements, and/or characteristics of AI. (Content knowledge and communication) SLO2. Recognize, identify, describe, define and/or explain applications of AI in multiple domains. (Critical thinking and communication)
Use & Apply AI	Applying AI knowledge, concepts and applications in different scenarios	>50%	SLO3. Select and/or utilize AI tools and techniques appropriate to a specific context and application. (Critical thinking and content knowledge)
Evaluate and Create AI	Higher-order thinking skills (e.g., evaluate, appraise, predict, design) with AI applications	>50%	SLO4. Assess the context-specific value or quality of AI tools and applications. (Critical thinking) SLO5. Conceptualize and/or develop tools, hardware, data, and/or algorithms utilized in AI solutions. (Critical thinking)
AI Ethics	Human-centered considerations (e.g., fairness, accountability, transparency, ethics, safety)	>50%	SLO6. Develop, apply, and/or evaluate contextually appropriate ethical frameworks to use across all aspects of AI. (Critical thinking and content knowledge)

[a] The initial identification of AI content percentages may change once more courses are evaluated and managed through this process.

more are being added each semester as more AI expertise is built across campus. For example: 'GeoAI: Geographic Artificial Intelligence and Big Data' is a newly developed (2022) certificate program offered in the Geography Department. GeoAI provides novel approaches for addressing a variety of geospatial challenges in the real world (Hu et al., 2019; Janowicz et al., 2020). This certificate develops transferable skills in GeoAI to address issues impacting our environment and societies. GeoAI training is critical given the projected growth of approximately 16% in this industry by 2050 (Janowicz et al., 2020), and so establishing these focused areas of expertise and training at UF is timely.

4.3.3. AI undergraduate scholars and AI undergraduate medallion programs

Another QEP Initiative is the AI Undergraduate Scholars and AI Undergraduate Medallion Programs. The AI Undergraduate Scholars program is based on existing programs offered through the UF Center for Undergraduate Research, including research opportunities directly between undergraduates and AI faculty programs. AI Undergraduate Scholars apply to work on AI related research topics with faculty and are awarded on a semester or annual basis. For the AI Medallion Programs, undergraduate AI Scholars complete a series of courses, experiences, and other AI-related activities as designated by the AI^2 Center. Students meeting the minimum requirements receive an AI Medallion to recognize them at graduation. Additional activities and courses include experiential learning in the form of internships, co-ops, study abroad, community service, research, public service, or design competitions for credit hours. The medallion and scholars programs are modeled on existing, successful programs at UF, but are adapted to feature AI scholarship. Mentors for the AI Undergraduate Scholars program are affiliate faculty of the AI^2 Center. AI Scholars are showcased during conferences and other professional events held by the AI^2 Center.

This initiative includes the development of **C**ourse-based **U**ndergraduate **R**esearch **E**xperience (CURE) classes within the existing framework already established by the UF Center for Undergraduate Research. CURE are research-focused courses that can feature AI as a core component. In addition, the initiative includes team-based courses focused on an industry-presented challenge within AI, and with the industry serving as a partner/client, that we refer to as 'I-CURE' courses. Teams are composed of students from different disciplines assembled to solve a particular AI industry question and are led by a faculty member. Industry partners have provided feedback regarding their interest in these I-CURE opportunities which are developed in concert with the Career Connections Center (C3) at UF.

All activities mentioned are managed through the AI^2 Center.

4.3.3.1. I-CURE courses with industry partners. One approach to address this gap or need within our educational curriculum is to engage in CURE-based AI-focused courses. We propose to use the CURE courses as a pedagogical tool to link AI techniques and approaches to problems to solve real-world questions posed by our industry partners (I) in a truly innovative manner. I-CUREs involve whole classes of students in addressing a research question or problem that is of interest to stakeholders outside the classroom. Here, our industry partners will propose real-world problems to our class, which is led by faculty, and will then work on AI-based solutions, with an interdisciplinary team. During an I-CURE, students will engage in scientific practices, such as collecting and analyzing data and developing and critiquing arguments, learning AI-based approaches and potential solutions, and communicating with each other and industry partners in frequent meetings – just as in a work environment. Course-based undergraduate research experiences (CUREs) are being championed as scalable ways of involving undergraduates in science research, and here we integrate with a specific focus on AI-based approaches and solutions to develop our I-CURE's. Studies of CUREs have shown that participating students achieve many of the same outcomes as students who complete research internships (Corwin et al., 2017). I-CURE has added potential given the link with industry partners and faculty leader and interactions with the AI^2 Center and Career Connections Center. Student and faculty experiences, linked directly to engagement with our industry partners, while learning essential real-world, transferable skills, will benefit our students immensely, and will be open to ALL undergraduate students regardless of background. This is truly an innovative and timely *AI Across the Curriculum* approach to learning.

Our objectives are 1) Design innovative AI courses to foster teamwork from different disciplines to solve a complex problem or challenge posed by an industry partner; 2) Increase students' ability to work in interdisciplinary environments to solve a problem and thus to be better prepared for workforce needs, and 3) Foster connections between student learning and AI employer needs with a direct linkage to the Career Connection Center. Expected outcomes of these objectives include 1) New course pedagogy to facilitate student learning on complex topics in AI; 2) Students entering the workforce with greater ability to exploit the synergy and productivity of diverse team environments and 3) Development of processes to better link student learning with industry/employer skill and knowledge needs in the fast-paced technology and AI landscape.

4.3.4. AI career development and industry engagement

The Career Connection Center (C3) will prioritize equipping students with the knowledge and connections needed for the AI ready workforce. C3 will advance the university's AI initiative to create pathways for career development for students by 1) Educating students and campus about AI use in recruiting practices and changing workforce needs; and specifically, aiding students to articulate the AI competencies (skills, abilities, and personal attributes) they have developed. 2) Facilitating opportunities for AI to be applied in internships and experiential learning. Thus, C3 will expose students to career pathways available in AI through internships and other experiential learning experiences related to AI. C3 will work to provide experiential learning opportunities for students by working with faculty to showcase AI in the curriculum to address the need for an AI-ready workforce. 3) The C3 will partner across campus to launch the Comprehensive Learning Record (CLR) to highlight AI-related workforce skills of undergraduate students. By putting the discussion of workplace skills and real-world competencies upfront in the *AI Across the Curriculum* discussion, UF will provide an innovative approach to education that acknowledges the real-world needs for skills and literacies in AI across the undergraduate student body (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Ng et al., 2021; St Louis et al., 2021). Thus, rather than skills and competencies being an afterthought in the curriculum, it is front and center in the curriculum and program development at UF (Ahmad, 2019). C3 also connects over 2000 companies to our efforts with AI curriculum and workforce development.

The pedagogy we propose through the AI literacies and the QEP initiatives removes barriers often present at universities due to a silo structure and provides a more direct link between student learning and professional employment experiences. This pedagogical approach uses AI as the vehicle to create this cross-cutting and inclusive learning environment.

5. Discussion & conclusion

The basic question addressed here is "What will UF's *AI Across the Curriculum* Program" create? The goal in developing a highly innovative approach to a campus-wide *AI Across the Curriculum* program is to provide an opportunity for every undergraduate student to engage and learn about AI, both within their discipline and more importantly, in an interdisciplinary manner often more reflective of the real-world, workplace environment. In line with this goal, there is engagement across all colleges, as highlighted by the 106 AI faculty hires located within all 16 UF colleges (Fig. 1). Additional benefits of this program include

enhanced workforce development and career readiness of our students. Through innovative partnerships, such as the I-CURE courses, increased internship opportunities and a dedicated faculty and staff to support institutional engagement, we anticipate increased relationships with alumni and industry partners. The central goal of this initiative is to embrace the need for students to develop real-world marketable AI skillsets. This includes AI skills and knowledge, awareness of the implications of AI in society and an improved engagement with and communication about AI. These all seek to help develop "*Successful digital citizens*" and "*global collaborators*" as well as foster more engaged faculty, students, and staff (Zimmerman, 2018). The intellectual output of this program will provide an innovative pedagogy for others to model, with the structure being adaptable to different campus-wide initiatives, not just AI.

The AI Across the Curriculum model will be evaluated using student learning outcomes (SLOs) directly tied to the AI literacies and goals related to the model initiatives. The SLO evaluation process will be integrated into course assessments using rubrics that indicates mastery or non-mastery for the relevant SLOs. SLOs include 1) identify, describe, and/or explain the components, requirement and/or characteristics of AI; 2) recognize, identify, describe, define, and/or explain applications of AI in multiple domains; 3) select and/or utilize AI tools and techniques appropriate to a specific context and application; 4) develop, apply, and/or evaluate contextually appropriate ethical frameworks to use within AI; 5) assess the context-specific value or quality of AI tools and applications; and 6) conceptualize and/or develop tools, hardware, data, and/or algorithms utilized in AI solutions. The assessments will be collected and evaluated each semester to identify successes and opportunities for improvement. Likewise, six initiative-based goals will be assessed using specific metrics. Goals will be assessed annually. As an example, one goal is "AI courses will be developed to ensure that courses from all four AI literacy topics are accessible to all undergraduate students in each college." The metrics to assess this goal are 1) number of curricular offerings within each AI area by college and 2) undergraduate student enrollment in AI courses in each area by college. As data are collected and evaluated, we anticipate modifications will be needed to SLO rubrics and goal metrics and perhaps the SLOs and goals themselves. We will remain flexible and nimble with the assessment process to best meet QEP requirements and AI Across the Curriculum adaptive needs. Given the complexity of gathering data across 16 colleges in a large institution, we anticipate there will be some data management hurdles that will need to be resolved within the UF data collection systems as the evaluation process initiates. To this point, the AI Across the Curriculum team continually meets with university managers to update the mechanisms for data collection such that they best align with the most current university capabilities. Given this curriculum model has been developed through cross-college collaborations with care toward specific college needs and low burden for engagement, we are optimistic of its potential for success. However, data to support the full breadth of the model and its initiatives will not be available for several years given the 4-year cycle of the undergraduate programs. Some data have been collected (with less detail) to track instructor or college identified AI courses, with 2022 UF campuswide numbers indicating over 6000 students enrolled in over 200 AI courses which provides a draft baseline. The AI curriculum model presented herein is preparing our future workforce with critical, real-world skills and AI technological expertise. AI literacy is critical for our students in the 21st century (Buckingham Shum & Deakin Crick, 2016; Cantú-Ortiz et al., 2020; Ng et al., 2021; St Louis et al., 2021) as clearly highlighted, but it is key for everyone – not just within technology and related STEM fields. This model is innovative in its '*AI Across the Curriculum*' design, engaging with the different approaches and styles of learning developed, and transformative within higher education in its transdisciplinary approach and accessibility across all colleges and majors across campus.

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Declaration of competing interest

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