EMPOWERING SMALL LIBERAL ARTS INSTITUTIONS: DESIGNING AN IN-DEPTH CURRICULUM FOR INTEGRATING AI AND ML EDUCATION WITH PEDAGOGICAL CONSIDERATIONS

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ABSTRACT

The integration of artificial intelligence (AI) and machine learning (ML) into academic curricula has become increasingly important in contemporary institutions. However, small liberal arts institutions face unique challenges in adapting their programs to meet the growing demand for AI and ML expertise. This article explores the significance of providing computer science graduates from these institutions with a comprehensive understanding of AI and ML systems. The proposed curriculum encompasses problem-solving techniques, algorithm design, data preprocessing, model training, and ethical considerations specific to AI and ML. Pedagogically, an emphasis is placed on practical assignments, projects, and collaborative learning to foster critical thinking and creative problem-solving skills among students. Furthermore, integrating AI and ML concepts across disciplines enables students to explore these technologies' broader implications and ethical dimensions. Small liberal arts institutions can capitalize on their distinctive educational environments to promote interdisciplinary collaborations and provide students with a holistic understanding of AI and ML applications. In conclusion, adapting small liberal arts institutions to incorporate AI and ML education is crucial for preparing computer science graduates to meet the evolving demands of the modern workforce. By embracing these advancements and tailoring their programs accordingly, these institutions can empower their students with the essential skills and knowledge to thrive in an AI-driven world. The article also discusses the advantages, limitations, and potential future steps in integrating AI and ML education into small liberal arts institutions.

KEYWORDS

Artificial Intelligence, Machine Learning, Small Liberal Arts Institutions, Curriculum Development, Pedagogy, Computer Science Education, Interdisciplinary collaboration

1. INTRODUCTION

The rapidly expanding field of computer science (CS) encompasses various subjects, including artificial intelligence (AI), machine learning (ML), and data science. With the AI market projected to reach staggering figures by 2030 (see Figure 1) [1] and significant investments being made globally, it is evident that these areas are becoming increasingly vital for professionals in the field [2]. While many CS programs offer elective courses in AI, ML, and related topics, smaller institutions, particularly liberal arts colleges, and universities, face challenges in providing these electives consistently due to limited faculty resources and low course enrollment. Consequently, some students may graduate without exposure to these crucial subjects, which are increasingly relevant in the modern computing landscape.

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However, we argue that AI and ML are foundational elements of a comprehensive CS program in today's world. As new graduates enter the workforce, they will likely encounter AI, ML, and data science in their professional endeavors. The integration of AI into business and government information systems makes it essential for CS graduates to possess a solid understanding of these fields. Despite the constraints faced by smaller institutions, including AI and ML in the CS curriculum is critical for equipping students with the necessary skills and knowledge to meet the demands of the evolving industry.

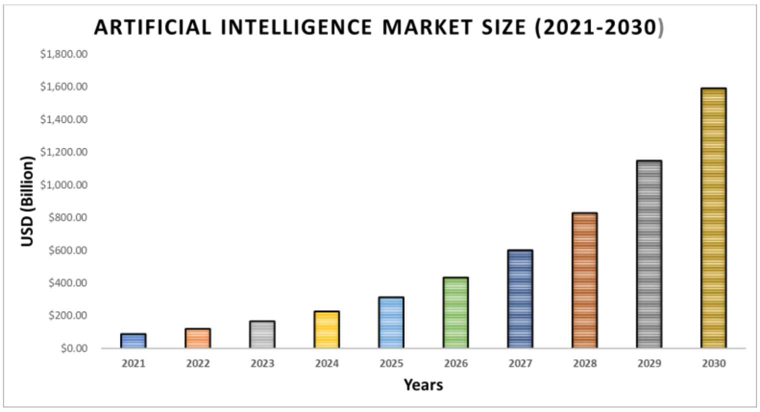

Figure1. Exponential Growth of the Artificial Intelligence Market

At many schools, classes such as AI, ML, and data science are offered as electives intermittently, not as part of the core. Other areas compete for attention, including software engineering, databases, networks, compilers, graphics, etc. It's a long list. Some students might find themselves in some AI course – if they have time and for small schools at least, if the timing is right, or they might find themselves in an ML course or a course that involves data models. Rarely will they be able to take all three, at least not at smaller schools with limited faculty.

However, many schools do not include ML in that core set of classes. Shapiro, Fiebrink, and Norvig address the issue in their 2018 paper: "The growing importance of ML thus raises challenging questions for CS education: How should practical and theoretical ML topics now be integrated into undergraduate curricula? Furthermore, how can we make room for expanded ML content in a way that augments— rather than displaces—classical CS skills within undergraduate degree programs whose duration must remain static?"[3]

Additionally, a 2020 publication from a task force including representatives of the ACM and IEEE, among several other industry and academic stakeholders, points out that AI and related areas of computing "have blossomed during the last ten years. AI and its allied field of robotics have become prevalent fields of study in computing. Although no formal professionally endorsed AI curriculum exists at the time of this writing, a curricular recommendation in these areas has the potential to emerge in the next few years"[4].

Of course, looming in the not-to-distant future is another challenge for traditional CS education – AI systems that themselves can write and explain computer code, among other things. ChatGPT [5] recently debuted on the internet and can successfully write and debug complicated computer code.In any case, there are two questions at work here. First, why should small liberal arts institutions concern themselves with computer science? Why not leave it to large engineering programs? Secondly, given the small student body and faculty and staff limitations, it is possible to provide students with a grounding in AI and ML while maintaining the necessary core classes for a CS degree.

This article explores the distinctive role of small liberal arts institutions in computer science (CS) education and the challenges they encounter when incorporating AI topics into their existing curriculum. Additionally, it investigates potential approaches for introducing CS majors to fundamental concepts of AI, data modeling, and machine learning (ML) within a single, condensed course. The AI course at Bellarmine University in Louisville, KY,is an illustrative example. Bellarmine University, with an undergraduate enrollment of 2,484 students and a graduate enrollment of 809 students as of 2020, provides valuable insights into this context.

2. LIBERAL ARTS AND COMPUTER SCIENCE EDUCATION

Traditionally large CS and engineering programs have concentrated on providing technical and engineering expertise for CS majors. Any additional courses usually focus on math, with the remaining hours filled by general education requirements.Liberal arts education includes another mandate that provides forbut differs from general education, what can be thought of as the core part of the curriculum, in that it should be intentionally interdisciplinary and reflective, requiring "the multitude of perspectives, ways of thinking, methods and knowledge content anchored in a variety of disciplines. It requires its students to study beyond a single subject or within one family of disciplines… it lays the foundation for learning how to interpret, interrogate or to make new knowledge framed in the constructs of various fields"[6]. As Wolfson, Cuba, and Day point out, the benefits of liberal arts education seem to accrue most to those who delve deeply into a second field rather than surveying a variety of areas of study and "general education" coursework [7]. As a surprising fact, liberal arts colleges produce proportionally more PhDs in science [8].

The multidisciplinary approach to CS that a liberal arts institution can provide is precious to those entering the field. It is important to note that CS now plays a role in almost every study area. CS is everywhere. All science is computer science[9]. In other words, CS has become central to virtually all fields of study in some fashion and could be called the most liberal of the liberal arts. As Steve Jobs, former Apple CEO, put it: "… science and CS is a liberal art; everyone should know how to use, at least, and harness in their life. It should not be relegated to 5 percent of the population over the corner. It's something that everybody should be exposed to, and everyone should have mastery of to some extent, and that's how we viewed computation and these computation devices"[10].

In their 2022 paper, Brodleyet al.describe their program at Northeastern University, where students "can choose among three computing majors like CS, Data Science or Cybersecurity and 42 combined majors, which combine of the three computing degrees with one of 29 distinct majors in other fields"[11]. One effect of the program has been to create greater gender diversity in CS majors. The term "X+CS" is a similar concept whereby students in fields of study other than CS add CS to their major. Liberal arts institutions are in a position not only to combine specific programs to form majors but to allow students to mix and match classes, creating their degree programs.

Smaller schools have advantages and limitations. Smaller enrollment means classes often are taught by faculty with terminal degrees and excellent student-teacher ratios, with the result of more personal attention. The core philosophy of liberal education focuses on analytic thinking and social responsibility. However, liberal arts colleges and universities are constrained in many ways that do not face larger institutions. They face a mandate to graduate students with a wider variety of educational experiences. Smaller enrollment means class sizes tend to be smaller, and a crisis in student demographics is likely to make enrollments smaller or constrain their growth[12]. Some classes will not have enough students to be offered every term or year. This burdens students to show at least intermediate competence in the second field of study, limiting the time and course availability for their major. This brings us back to AI and ML. With all of the constraints we have placed on liberal arts students in CS programs,there is room for additional classes – data science, AI, and ML. Students might have one opportunity to take one course in one of those topics in their four-year tenure or find themselves with only one. At the very least, they must be introduced to those topics before leaving university.

2.1. Computer Science + X

The liberal arts approach to CS education extends beyond the traditional boundaries of the discipline by integrating CS with diverse fields, leading to the emergence of CS+X programs. This abstract delves into the skills required for CS + X graduates, where X represents a complementary discipline or specialization. CS + X graduates are expected to have a solid grounding in CS fundamentals, encompassing programming, data structures, algorithms, and software development. These programs combine the analytical and problem-solving skills of CS with the critical thinking, creativity, and interdisciplinary perspectives of the liberal arts.Furthermore, they are required to acquire domain-specific knowledge in their chosen X field, which can span diverse areas such as biology, finance, psychology, and design. Here we are discussing some common CS+X disciplines.

2.1.1. CS+ Biology/ Bioinformatics

Integrating CS with biology or bioinformatics creates a powerful interdisciplinary field that combines computational techniques with biological research and applications. This synergy enables scientists to leverage the vast amounts of biological data generated through advancements in genomics, proteomics, and other 'omics' technologies [13]. Here are some key aspects of CS + Biology/Bioinformatics:

- **Data Analysis:** CS plays a crucial role in analyzing and interpreting large-scale biological data, such as DNA sequences, gene expression profiles, protein structures, and metabolic pathways. Computational algorithms and machine learning techniques are used to extract meaningful patterns, identify genes or proteins of interest, and uncover underlying biological mechanisms.
- **Computational Modeling:** CS provides tools and methodologies for constructing computational models that simulate biological systems, ranging from cellular processes to ecological interactions. These models help researchers gain insights into complex biological phenomena, predict system behavior, and design experiments to validate hypotheses.
- **Genomic Data Mining:** CS techniques are utilized to mine and analyze genomic data to identify disease-associated genes, understand genetic variations, and predict protein functions. This contributes to advancements in personalized medicine, drug discovery, and genetic engineering.
- **Bioinformatics Tools and Databases:** CS plays a pivotal role in the development of bioinformatics tools and databases that facilitate the storage, retrieval, and analysis of biological data. These resources enable researchers to access and integrate diverse biological data sets, accelerating discoveries and fostering collaborations.

Integrating CS and biology/bioinformatics is driving advancements in genomics, computational biology, synthetic biology, and precision medicine. It offers opportunities to solve complex biological problems, unravel the mysteries of life, and contribute to advancements in healthcare, agriculture, and environmental sustainability.

2.1.2. CS+ Finance

The combination of computer science (CS) with finance creates a dynamic field that leverages computational tools and algorithms to enhance various aspects of finance [14]. Here are key areas where CS + Finance intersects:

- **Financial Modeling:** CS techniques enable the development of sophisticated mathematical models to simulate and predict financial scenarios. These models help in pricing derivatives, valuing assets, and assessing investment strategies. Monte Carlo simulations, optimization algorithms, and machine learning algorithms are often employed to improve the accuracy and efficiency of financial models.
- **Risk Analysis:** CS is crucial in risk assessment and management within the financial industry. Computational tools and algorithms are used to analyze and quantify different types of risks, such as market risk, credit risk, and operational risk. Techniques like value-at-risk (VaR), stress testing, and scenario analysis are applied to evaluate and mitigate risks in investment portfolios and financial institutions.
- **Financial Data Analysis:** CS techniques are utilized to process and analyze large volumes of financial data. This includes data cleaning, integration, mining, and statistical analysis techniques. By leveraging these tools, financial professionals can extract meaningful insights, identify patterns, and make informed decisions based on historical and real-time financial data.
- **Algorithmic Investing:** CS algorithms and machine learning techniques are employed to automate investment decisions. These algorithms analyze vast amounts of financial data, identify patterns, and execute trades based on predefined rules or learned patterns. Algorithmic investing can improve trading efficiency, reduce human biases, and enhance portfolio management strategies.

The integration of CS and finance is transforming the financial landscape, enabling more accurate risk assessment, advanced trading strategies, data-driven decision-making, and technological innovations. This interdisciplinary field provides exciting opportunities for professionals to combine their expertise in CS with finance, contributing to developing more efficient and resilient financial systems.

2.1.3. CS + Design

The fusion of computer science (CS) with design creates a powerful interdisciplinary field that combines computational techniques with design principles and user experience [15]. Here are key aspects of CS + Design:

- **User Interface (UI) Design:** CS plays a crucial role in creating interactive and user-friendly interfaces for software applications, websites, and digital products. Computational techniques are employed to design intuitive layouts, navigation systems, and visual elements that enhance user engagement and satisfaction.
- **Computer Graphics and Visualization:** CS techniques are utilized to generate realistic computer graphics, simulate virtual environments, and create visually compelling experiences. This includes rendering techniques, 3D modeling, animation, and virtual reality (VR) or augmented reality (AR) applications. Visualization techniques are also applied to represent complex data in an understandable and visually appealing manner.
- **Human-Computer Interaction (HCI):** The integration of CS and design focuses on understanding and improving the interaction between humans and computers. This involves studying user behavior and cognitive processes and designing interfaces that

meet user needs and preferences. CS techniques, such as usability testing, user research, and prototyping, are employed to enhance digital products' usability and user experience (UX).

- **Design Automation:** CS algorithms and techniques automate design processes and optimize design solutions. This includes generative design, where algorithms generate and iterate design options based on predefined parameters or constraints. Computational techniques also support parametric design, where design elements can be adjusted dynamically based on user inputs or system requirements.

The integration of CS and design empowers professionals to create innovative and user-centered digital experiences, leveraging computational techniques to enhance usability, aesthetics, and functionality. CS + Design professionals contribute to diverse fields, including user experience design, interaction design, information design, gaming, virtual reality, and digital product development. By combining CS with design principles, practitioners can create impactful and engaging experiences that meet the evolving needs of users in our increasingly digital world.

2.1.4. CS+ Environmental Science

CS with environmental science creates a powerful interdisciplinary field that leverages computational methods to analyze environmental data, model complex environmental systems, and tackle pressing environmental challenges [16]. Here are key aspects of CS + Environmental Science:

- **Environmental Data Analysis:** CS techniques enable the processing, analyzing, and interpreting large and diverse environmental datasets. This includes data from remote sensing, environmental monitoring stations, ecological surveys, climate models, and citizen science initiatives. Computational tools and algorithms help identify patterns, extract meaningful information, and derive insights from environmental data.
- **Environmental Modeling and Simulation**: CS plays a crucial role in modeling and simulating environmental systems. Computational models simulate complex ecological systems, climate dynamics, hydrological processes, and environmental impacts. These models help in understanding the behavior of environmental systems, predicting future scenarios, and informing decision-making for sustainable resource management and conservation.
- **Geospatial Analysis and Mapping:** CS techniques are employed for geospatial analysis, mapping, and visualization of environmental data. Geographic Information Systems (GIS) and remote sensing technologies enable the integration and analysis of spatial and temporal environmental data, facilitating landscape characterization, habitat mapping, land-use planning, and disaster management.
- **Climate Change and Environmental Impact Assessment:** CS + Environmental Science contributes to assessing and understanding the impacts of climate change on ecosystems, biodiversity, and natural resources. Computational methods are utilized to analyze climate data, simulate climate scenarios, and assess the vulnerability and resilience of ecosystems. These analyses provide insights into the potential effects of climate change and aid in developing mitigation and adaptation strategies.

Integrating CS and environmental science offers opportunities to address complex environmental challenges, such as climate change, habitat loss, pollution, and natural resource management. By leveraging computational methods, CS + Environmental Science professionals can contribute to sustainable development, conservation efforts, and informed decision-making, ultimately fostering a more resilient and sustainable future by integrating scientific knowledge with technological advancements.

These are just a few examples, and numerous other disciplines can be combined with CS to create CS+X programs, depending on the specific interests and needs of students and the industry demands.

3. ARTIFICIAL INTELLIGENCE IN THE COMPUTER SCIENCE CURRICULUM

Integrating AI and ML into the core CS curriculum is becoming increasingly important for small liberal arts institutions. While a multidisciplinary and pedagogically liberal approach is valuable, addressing the technical skills and knowledge required in today's workplace is crucial, especially considering the rapid advancements in AI and ML.The traditional CS curriculum typically covers fundamental topics such as programming, algorithms, data structures, and computer architecture. However, with the emergence and growth of AI and ML, additional subfields have gained prominence, including cybersecurity, cloud systems, data science, and ML itself. These subfields bring about new challenges and opportunities, necessitating the development of diverse technical skills among students.

ML, in particular, represents a significant departure from the traditional CS curriculum due to its focus on algorithms and statistical models that enable computers to learn and make predictions from data. Integrating ML into the core CS curriculum can offer several benefits to students. It equips them with the necessary skills to understand and work with ML algorithms, enabling them to develop intelligent systems, data-driven applications, and predictive models. ML skills are highly sought after in industries such as healthcare, finance, marketing, and technology, making it essential for students to be well-versed in this field.To effectively integrate AI and ML into the core CS curriculum at small liberal arts institutions, several approaches can be considered:

- **Curriculum Expansion:** Develop new courses or modify existing ones to incorporate AI and ML topics. This could include dedicated courses on machine learning, data science, or AI applications in specific domains. These courses can cover foundational concepts, algorithms, statistical models, and practical implementation.
- **Interdisciplinary Collaboration:** Foster collaborations between the CS department and other relevant departments such as mathematics, statistics, psychology, or business. AI and ML often intersect with these disciplines, and interdisciplinary projects can give students a holistic understanding of the field.
- **Hands-on Projects:** Emphasize practical implementation and project-based learning. Provide students with opportunities to apply ML techniques to real-world problems through projects, case studies, or internships. This approach allows students to gain hands-on experience and develop critical problem-solving skills.
- **Research Opportunities:** Encourage undergraduate research in AI and ML. Small liberal arts institutions can leverage faculty expertise and resources to offer research opportunities to interested students. This not only enhances their technical skills but also fosters innovation and collaboration.
- **Industry Partnerships:** Establish connections with industry partners to expose students to real-world applications of AI and ML. Industry collaborations can offer internships, guest lectures, and access to relevant datasets or tools, enriching students' learning experiences.

Incorporating AI and ML into the CS curriculum at small liberal arts institutions requires careful planning, collaboration, and adaptation. By doing so, these institutions can ensure that their students are well-prepared to meet the demands of the rapidly evolving technological landscape while maintaining the values of a liberal arts education.

4. COMPUTER SCIENCE PROGRAMS AT BELLARMINE UNIVERSITY: BA DEGREE WITH ARTIFICIAL INTELLIGENCE & MACHINE LEARNING COURSE

Bellarmine University offers a comprehensive Bachelor of Arts (BA) degree program in Computer Science (CS) that integrates interdisciplinary elements and provides students with a well-rounded education. The program encompasses core CS concepts while incorporating mathematics, physics, foreign language proficiency, and the flexibility to pursue minors or second majors. An AI class was recently introduced, covering classical AI, data science, and ML within a single term. The BA degree program at Bellarmine University aligns with a traditional Bachelor of Science (BS) degree in CS, including a mathematics minor and university-level physics courses. This ensures that students develop strong analytical and problem-solving skills necessary for success in CS. Incorporating mathematical and scientific components prepares students to tackle technical challenges in their future careers.

Recognizing the evolving landscape of CS and students' diverse interests, Bellarmine University offers an alternative BA program. This program reduces the emphasis on mathematics and allows students to pursue a minor or second major of their choice. This flexibility enables students to tailor their degrees to align with their interests and career goals.Bellarmine University has responded to the growing importance of AI and ML by introducing an AI class in its CS curriculum. This course provides a comprehensive overview of classical AI, data science, and ML in a single term. Students gain exposure to theoretical concepts, practical techniques, and ethical considerations related to AI and ML. This comprehensive approach allows students to understand the interconnectedness of various aspects of AI and develop a well-rounded perspective on the field.This comprehensive approach allows students to understand the interplay between different aspects of AI and develop a well-rounded perspective on the field shown in Table 1.

Table 1. Proposed Bachelor of Arts in Computer Science Course List

Year	Course	Course Description
Freshman (1st year)	CS1XX: Programming Fundamentals:	Introduction to fundamental concepts of procedural programming, including data types, control structures, functions, arrays, files, debugging, and problem-solving techniques
	CS1XX: The Object-Oriented Paradigm	Concepts of object-oriented programming, including classes, inheritance, polymorphism, algorithms, search and sorting techniques, software engineering issues, and generic programming
Sophomore (2nd year)	CS2XX: Data Structures:	Algorithmic notation, algorithm design, elementary data structures and their storage representations, linear and nonlinear data structures, memory management, file processing, and sorting and searching algorithms
	CS2XX: Logic Design	Introduction to logic gates, combinational and sequential circuits, circuit simplification using Karnaugh maps and Boolean functions, flip-flops, counters, registers, and electronic implementation of binary arithmetic
Junior (3rd year)	CS 3XX: Operating Systems	Classification schemes for operating systems, the resource-manager model, system structure, memory management, process management, design techniques, and implementation of a simple operating system and related software
	CS Elective I	Listed below
	CS 3XX:	The purpose of compilers, different types of compilers,

	Compiler Construction	formal language concepts including syntax and grammar characteristics, linguistic analysis, parsing techniques, and interpretative languages such as assembly language
	CS3XX: Algorithms	Algorithm design techniques, including backtracking, heuristics, recursion, and simulation, as well as the experimental and analytical determination of algorithm performance. It also explores the application of algorithm design in various areas of computer science, such as AI and systems programming
Senior (4th year)	CS4XX: OverviewofAI	▪ See Table 2
	CS4XX: Software Design and Development	Design techniques, formal models of structured programming, organization, and management, estimating program libraries, documentation, and organization of a large-scale project by students
	CS Elective II	▪ Listed below
	CS 4XX: Data Communications and Computer Networks	The comparison between traditional star networks and distributed designs, access methods, protocols, data communications hardware, software, transmission media, systems design considerations, and the implementation and upgrading of computer networks
	CS4XX: Computer Science Capstone	Completing a significant design and development project, including a written report and an oral presentation, a comprehensive exam in computer science
CS Electives	▪ Aerial Robotics ▪ Database management system ▪ Machine learning on Cloud ▪ Visual Programming	

5. A Proposed First Course in Artificial Intelligence

To effectively address the requirements of CS students in today's AI-centric work environment, we propose a comprehensive first course in AI that covers essential theoretical foundations, classic AI algorithms, ML concepts, and basic neural networks. While time constraints limit the breadth of topics that can be covered, this course aims to provide a practical and broad basis for students to grasp AI concepts quickly in future academic or professional settings.

The course outline includes the following key components:

1. Establishing a Theoretical Foundation:

    - Introduce students to the fundamental principles and concepts that underpin the field of AI.
    - Cover intelligent agents, problem-solving, knowledge representation, and reasoning topics.

2. Classic AI Algorithms:

    - Familiarize students with commonly used and well-established algorithms in classic AI.
    - Provide basic programming and analysis skills to implement and understand these algorithms.
    - Explore topics like search algorithms, constraint satisfaction problems, and game playing.

3. Introduction to ML and Data Science:

   - Introduce students to essential concepts in ML and data science.
   - Emphasize a hands-on and programmatic approach to understanding these concepts.
   - Cover supervised and unsupervised learning, regression, classification, and evaluation metrics.

4. Connectionist Concepts and Basic Neural Networks:

   - Familiarize students with connectionist models and basic neural networks.
   - Introduce the workings of neural networks and their applications in AI.
   - Cover topics like perceptron, activation functions, feedforward networks, and backpropagation.

While it is not feasible to cover every topic in classic AI, data science, and ML within the limited timeframe of the course, careful selection of individual topics ensures that students gain a broad and practical understanding. Students are assumed to have already taken prerequisite courses such as data structures, algorithms, and discrete mathematics. Some topics, such as predicate logic, may have been adequately covered in discrete math and can be referenced as needed in the AI course.

Specific topics are deemed indispensable for problem-solving in AI and should not be omitted. For example, various graph search strategies serve as essential techniques for problem-solving in AI and general agent-based problem-solving scenarios. By including such material, the course equips students with the necessary skills for AI problem-solving and provides a foundation for future learning in the field.

Overall, this proposed first course in AI aims to balance theoretical foundations, practical implementation, and exposure to crucial AI subfields. By carefully selecting and covering essential topics, students are provided with a solid basis to further exploration in subsequent courses, research endeavors, or professional AI work.Many topics are covered in our proposed course (see Figure 2).

Figure 2. Topics in a proposed AI course

The proposed course content and pedagogy attempt to answer many requirements for CS students facing AI in the current and near-future work environment. The course contains two major sections. The first part covers the concept of a "rational agent" operating in an environment using "percepts" and "actuators," along with theoretical knowledge of general problem-solving using traditional AI techniques [17]. The second part consists of various ML models for real-world problem solving, including supervised and unsupervised techniques, followed by an introduction to neural networks.

The course at our institution uses arguably the most popular AI text, "Russell and Norvig's AI: A Modern Approach," before moving away from the text in the second half of the course. Russell and Norvig are used to establish a paradigm or framework for considering the problem of AI in general. The second half of the term is used to discuss ML. It begins with a discussion of supervised and unsupervised learning, followed by a meeting of the theoretical foundation of linear regression with examples with Python.

Various resources are used to teach the data model-centric portion of the course, but no actual text is required. Part 1 discusses symbolic AI, and Part 2 introducesML. The topics, instructional materials, and learning activities are summarized in Table 2.

Table 2. The First Course on Artificial Intelligence Topics

Topics	**Instructional Materials**	**Learning Activities**
1.0 Introduction to Artificial Intelligence	▪ Definition of AI ▪ Fields that contribute to AI ▪ Historical milestones that have led to our present view of AI ▪ The current state of AI	Syllabus Quiz: Understand the syllabus Assignment: P vs. NP and summary paper
1.1 Intelligent Agents	▪ The concept and types of Rational Agents ▪ Percepts and actuators ▪ Various types of environments ▪ Performance measures	Assignment: Code a simple reflex agent vacuum world with performance measures
1.2 Solving Problems by Searching	▪ Types and cost of uninformed searches ▪ Search algorithm step by step ▪ Search to find a goal state ▪ State Spaces	
1.3 Informed Search	▪ Types and cost of informed searches ▪ Various informed search algorithms ▪ How search is used to find an optimal goal state ▪ Heuristics search	Team Assignment: Using a map of Romania (from Norvig), draw search trees/stacks/queues for Depth First Search, Uniform Cost Search, Greedy Best First Search, A* search
1.4 Game Theory and Adversarial Search	▪ Game theory background ▪ Minimax algorithm ▪ Game Tree Pruning	Assigns a graph. Students make a video showing graph traversal using Alpha-Beta Pruning.
2.0 MLOverview and Definition	▪ Supervised Learning ▪ Unsupervised Learning ▪ Reinforcement Learning	Midterm Exam over Part 1 of the course
2.1 Data Preprocessing and Introduction to Anaconda Python	▪ Python Libraries, Anaconda, Jupyter Notebook ▪ Missing Data and Outliers ▪ Encoding categorical variable	

	▪ Data Partitioning ▪ Data Dependency ▪ Overfitting	
2.2 Introduction to Linear Regression	▪ Linear Regression • Data Visualization and Dimension Reduction • Correlation • Covariance ▪ Explanation vs. Prediction vs.ML	Linear Regression Lab (See Table 3)
2.2 Linear Regression with the Boston Housing Dataset	▪ Preprocessing Boston Housing with Python ▪ Training and validation Sets ▪ Simple regression on the dataset ▪ Correlation: Pearson Coefficient ▪ Interpreting of Least Squares	
2.3 Multiple Linear Regression	▪ Simple vs. Multiple Linear Regression ▪ P-value, R, R-Squared and adjusted R-Square, RSME, and other essential statistics ▪ Variable Reduction ▪ Correlation Matrix Python ▪ Building the regression model ▪ Model Results ▪ Feature Selection, stepwise Refinement, best Subsets	Project 1 Proposal and ML project. Students select a dataset, use linear regression to model it and present their material in video and class presentation format.
2.4 Introduction to Artificial Neural Networks	▪ Perceptron ▪ Weights/Thresholds/bias ▪ Linear Regression with a Perceptron ▪ Sigmoid Functions and Sigmoid Neurons ▪ Recurrent Neural Networks vs. Convolution Neural Networks ▪ Deep neural network on Mnist dataset ▪ Gradient Descent, cost Function ▪ Back Propagation ▪ Introduction to the google cloud platform	
Final Project on ML topics (Group of two to three)	A video of your PowerPoint presentation and an explanation of your running code. ▪ KNN (K-nearest neighbors) ▪ Naïve Bayes ▪ Classification and Regression Trees (CART) (Decision Trees) ▪ Logistic Regression ▪ Association Rules (Apriori, Market Basket) ▪ Cluster Analysis	

Table 4 presents an outline of the course, highlighting the initial seven weeks that delve into the history of AI and its subfields. The course adopts the rational agent concept by Russell and Norvig, which emphasizes the importance of context and ontology in AI education. This concept views various applications, such as pricing homes in a changing economic landscape, pathfinding drones, or even hypothetical galactic overlords, as rational agents perceiving their environment through sensors and acting through actuators. The course is subdivided into four sub sections:

Section 1: Introduction to Artificial Intelligence (AI) In this section, students are introduced to the fundamental concepts of AI. They explore various approaches to AI, including discussions on rationality, intelligence, and the contributions of other disciplines to AI. The class delves into Alan Turing's definition of intelligence and the famous Turing Test. Students also understand important concepts such as agents, rational agents, percepts, agent functions, and different types of environments. The section covers single and multi-agent systems, deterministic and stochastic systems, episodic and sequential systems, static and dynamic systems, and discrete and continuous systems. By the end of this section, students will have a solid foundation in the core concepts of AI.

Section 2: Search Algorithms and Game Theory This section focuses on space searches, progressing from basic tree searches to more advanced algorithms. Students learn about different search strategies, including uniform cost and greedy searches, and culminate in the A* search algorithm. The subsequent module explores the game theory and the minimax algorithm, which is fundamental in decision-making in competitive environments. Topics like alpha-beta pruning are also covered, providing students with a comprehensive understanding of search algorithms and their applications in AI.

Section 3: Machine Learning (ML) The second half of the course delves into machine learning. Students learn about different data models within the context of a learning agent. The curriculum starts with lectures on supervised learning, unsupervised learning, and reinforcement learning. Practical aspects such as Python libraries, Anaconda, Jupyter Notebooks, and data preprocessing techniques are covered. Students gain insights into handling missing data, outliers, encoding categorical variables, data partitioning, data dependency, and avoiding overfitting.

Section 4: Hands-on Lab Work and Implementation This section emphasizes active student engagement during class periods. Students participate in hands-on lab work, working on machine learning models and neural networks. The instructor guides students through various exercises and examples. They start with an overview of learning, including supervised and unsupervised learning. The class progresses to implementing a linear regression example using real-world datasets like the Boston Housing dataset. Students learn to preprocess and partition the data, implement the model using Jupyter Notebooks, and analyze the results. This hands-on approach enables students to apply the knowledge gained in the earlier sections and develop practical skills in implementing machine learning algorithms.

Table 3. Linear Regression lab.

▪ Preprocessing the Boston Housing dataset: Students will import the dataset and perform necessary preprocessing steps, such as handling missing data, encoding categorical variables, and scaling numeric features. ▪ Splitting the dataset: Students will split the dataset into training and testing sets to evaluate the performance of the regression model. ▪ Building a linear regression model: Using the training set, students will build a linear regression model using the scikit-learn library. They will fit the model to the training data and examine the learned coefficients. ▪ Evaluating the model: Students will use the trained model to make predictions on the testing set and evaluate its performance. They will calculate metrics such as mean squared error (MSE) and R-squared to assess the model's accuracy. ▪ Visualizing the results: Students will create visualizations, such as scatter plots and regression lines, to understand the relationship between the independent and target variables. ▪ Interpreting the model: Students will interpret the coefficients of the linear regression model to understand the impact of each feature on the target variable.

Students are encouraged to actively participate in discussions, ask questions, and collaborate with their peers throughout the course. Integrating theory, practical examples, and hands-on lab work ensures a comprehensive learning experience in artificial intelligence and machine learning.

In computer science education, integrating artificial intelligence (AI) into the curriculum at small liberal arts schools brings together the strengths of a liberal arts education and the advancements of AI technology. Here, we explore the concept of liberal arts and its intersection with the computer science curriculum while considering the advantages and limitations faced by small liberal arts schools with limited faculty resources.

6. Advantages, Limitations and Mitigation Strategies

In computer science education, integrating artificial intelligence (AI) into the curriculum at small liberal arts schools brings together the strengths of a liberal arts education and the advancements of AI technology. Here, we explore the concept of liberal arts and its intersection with the computer science curriculum while considering the advantages and limitations faced by small liberal arts schools with limited faculty resources.

Liberal arts education emphasizes a well-rounded education that fosters critical thinking, creativity, and a broad understanding of various disciplines. It encourages students to develop strong communication skills, ethical awareness, and the ability to analyze and solve complex problems. Integrating AI into the computer science curriculum at liberal arts schools aligns with this philosophy by providing students with a multidisciplinary perspective and enabling them to explore the social, ethical, and humanistic dimensions of AI technology.

Advantages

- **Interdisciplinary Perspective:** Liberal arts education encourages students to bridge the gap between different fields of study. Integrating AI into the computer science curriculum at liberal arts schools allows students to explore the interdisciplinary nature of AI, its connections to fields such as ethics, philosophy, psychology, and sociology, and the broader societal implications of AI technology.

- **Ethical and Humanistic Considerations:** AI raises important ethical and social questions. Small liberal arts schools can foster discussions on AI's ethical implications, including bias, privacy, and transparency. By incorporating AI into the curriculum, students have the knowledge and critical thinking skills to navigate these ethical challenges.
- **Creative Problem-Solving Skills:** Liberal arts education emphasizes creative and critical thinking. AI presents complex problems that require innovative solutions. Integrating AI into the computer science curriculum at liberal arts schools nurtures students' creativity. It challenges them to think outside the box, fostering the development of unique approaches to problem-solving.
- **Adaptability and Versatility:** The integration of AI in the curriculum equips students with highly relevant skills in today's job market. AI technology is increasingly used across industries, and students with a liberal arts background in computer science and AI possess the adaptability and versatility to apply their skills in various professional contexts.

Limitations

- **Faculty Expertise and Resources:** Small liberal arts schools may face limitations regarding faculty expertise and resources to effectively integrate AI into the computer science curriculum. AI is a rapidly evolving field that requires specialized knowledge. Limited faculty resources may pose challenges in designing and delivering comprehensive AI courses and providing students with hands-on experiences.
- **Curriculum Constraints:** The computer science curriculum is often structured with specific core courses and limited flexibility. Integrating AI into the curriculum may require significant changes, such as developing or modifying new courses. Small liberal arts schools with limited faculty may face constraints in terms of time, curriculum space, and the ability to offer a wide range of AI-focused courses.
- **Technological Infrastructure:** AI often requires significant computational resources and access to large datasets. Small liberal arts schools may face limitations in providing the necessary technological infrastructure to support AI education, including high-performance computing resources, cloud platforms, and access to relevant datasets.

Mitigating Strategies

To address these limitations, small liberal arts schools can employ various strategies:

- **Collaboration and Partnerships:** Collaborating with other institutions, industry partners, or research organizations can provide access to expertise and resources in AI. Partnerships can include joint research projects, guest lectures, or shared access to computational infrastructure and datasets.
- **Professional Development:** Offering faculty development programs focused on AI can enhance faculty expertise and keep them abreast of the latest advancements in the field. Workshops, conferences, and training programs can provide opportunities for faculty to upgrade their AI knowledge and teaching skills.
- **Integration across Disciplines:** Rather than focusing solely on AI-specific courses, small liberal arts schools can incorporate AI concepts and applications across various disciplines. This approach allows for the integration of AI into existing courses, enabling students to explore the intersections between AI and other fields of study.
- **Leveraging External Resources:** Small liberal arts schools can supplement their curriculum by using online resources, open-source AI tools, and educational platforms. These resources provide students with access to AI-related materials, tutorials, and

practical exercises, compensating for limited faculty resources and technological infrastructure.

Integrating AI into the computer science curriculum at small liberal arts schools presents advantages regarding interdisciplinary perspectives, ethical considerations, creative problem-solving skills, and adaptability. While limitations such as faculty expertise, curriculum constraints, and resource limitations exist, mitigating strategies can be implemented to overcome these challenges and provide students with a comprehensive and well-rounded education in AI within the liberal arts context.

7. FUTURE DIRECTIONS & PLANNING FOR SUCCESS

The future direction and planning for the success of integrating AI and ML into the computer science curriculum of small liberal arts institutions, as well as the expansion of CS+X programs, should focus on several key aspects.

Firstly, ongoing collaboration with industry partners and staying updated with the latest advancements in AI and ML will be crucial. Small liberal arts institutions should establish strong connections with industry professionals, participate in relevant conferences and workshops, and continuously assess the changing needs of the job market. This will ensure that the curriculum remains relevant and aligned with industry demands, enabling students to acquire the necessary skills and knowledge to succeed in their careers.

Secondly, investing in faculty development and resources is essential. Small liberal arts schools may face limitations regarding faculty expertise and resources. Therefore, it will be crucial to provide opportunities for faculty members to enhance their knowledge and skills in AI, ML, and other related fields through training programs, workshops, and research collaborations. Additionally, securing resources such as computing infrastructure, software licenses, and datasets will support effective teaching and research in AI and ML.

Furthermore, fostering interdisciplinary collaborations within the institution and beyond is important for the success of CS+X programs. Small liberal arts schools can establish partnerships with other departments or institutions specializing in complementary disciplines, such as biology, finance, design, or environmental science. These collaborations can lead to joint research projects, shared courses, and experiential learning opportunities, enriching the educational experience for students and promoting cross-disciplinary innovation.

Lastly, promoting a culture of innovation, creativity, and ethical responsibility is vital. As AI and ML continue to shape various aspects of society, small liberal arts institutions need to emphasize these technologies' ethical implications and societal impact. Incorporating ethical considerations and critical thinking skills into the curriculum, fostering discussions on responsible AI development and deployment, and encouraging students to consider the broader implications of their work will prepare them to navigate the ethical challenges associated with AI and ML.

By focusing on these future directions and planning for success, small liberal arts institutions can effectively integrate AI and ML into their computer science curriculum, expand CS+X programs, and empower students to thrive in a technology-driven world. This approach will not only enhance the educational experience for students but also contribute to the advancement of AI research, address societal challenges, and shape the future of computer science education.

8. SUMMARY

This article examines the integration of artificial intelligence (AI) and machine learning (ML) into the computer science curriculum of small liberal arts institutions. It highlights the importance of incorporating these technologies to meet the growing demand for AI and ML expertise in various industries. The article discusses the advantages and limitations faced by small liberal arts schools, including the challenges of limited faculty resources and the need for interdisciplinary collaborations.

The recommended curriculum for AI and ML education includes problem-solving techniques, algorithm design, data preprocessing, model training, and ethical considerations. The pedagogy emphasizes practical assignments, projects, and collaborative learning to foster critical thinking and problem-solving skills. The article also emphasizes the broader implications and ethical dimensions of AI and ML, encouraging students to explore these aspects across disciplines.

The case study of Bellarmine University's AI course demonstrates how small liberal arts institutions can adapt their programs to incorporate AI and ML education. The university offers a comprehensive CS program that combines core concepts with interdisciplinary elements, providing students with a well-rounded education. The AI course at Bellarmine covers classical AI, data science, and ML in a single term, giving students exposure to theoretical concepts, practical techniques, and ethical considerations.

Overall, this article highlights the importance of AI and ML education in small liberal arts institutions and provides recommendations for curriculum development and pedagogical approaches. It emphasizes the need for these institutions to adapt to the evolving demands of the modern workforce and equip computer science graduates with the necessary skills and knowledge to thrive in an AI-driven world.

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