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(WIP) A New Curriculum Design in Aerial Computing: Teaching Ethical Decision Making with Drones through Socio-Scientific Inquiry

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Abstract

This work-in-progress paper presents a new curriculum that introduces undergraduate students to drone-centric cybersecurity and ethics in Sky-of-Privacy-Things (SoPT). Using a Socio-Scientific Inquiry (SSI) approach, students enhanced their technical skills and ethical awareness. Data analysis demonstrated the curriculum's effectiveness and its potential as a scalable model for integrating cybersecurity and privacy education into STEM fields.

Motivation for the Educational Intervention

We developed a new curriculum titled *Cyber-Aerial Computing* to engage undergraduate computer science (CS) students in exploring drone-centric cybersecurity and privacy, with the aim of improving *Sky-of-Privacy-Things* (SoPT) education and cultivating a high-performing, ethical engineering workforce. As concerns over misbehaving drones that threaten the security and privacy of individuals, communities, and the nation continue to grow, the need for ethics education in cyber-aerial computing has become increasingly urgent [1]. While universities offer ethics courses to meet ABET accreditation criteria, there is limited evidence regarding ethics education in drone-centric curricula that focus on privacy and security concerns in communities; indeed, most studies have concentrated on ethics in the context of drone warfare [2], [3]. As civil and commercial drone use expands in communities, significant research and educational efforts are needed to effectively prevent privacy and security breaches caused by drones.

Summary of the Intervention

This 16-week elective course is designed for junior and senior students at a four-year university in the southwestern region of the United States. A total of 44 undergraduate students from CS, computer engineering, and mechanical engineering enrolled in the course in Spring 2024.

Research Foundation for New Drone-Centric Curriculum

We designed this course based on recent CS research on drones, specifically leveraging drones to protect users from privacy invasion and information leakage [4], [5]. Each drone is treated as an autonomous object, designed to preserve its own privacy through pre-programmed movements and control via a remote user's smartphone. Multiple cameras and sensors can be embedded into the smartphone for enhanced portability and usability. Here, SoPT facilitates planned operations while safeguarding privacy- and security-sensitive information from adversaries, whether in existing or infrastructure-less networks. SoPT is a hybrid system where devices, sensors, and low-altitude drones communicate directly or via multi-hop relays, assuming the presence of potential adversaries engaging in privacy-invasive attacks or other malicious activities.

Socio-Scientific Inquiry

The development of the new course was guided by the socio-scientific inquiry (SSI) framework. SSI is an educational approach designed to engage students in inquiry that emphasizes complex societal problems and ethical decision-making through scientific and technical solutions [6]. SSI is characterized by driving questions, complexity, and conflicting viewpoints [7]. In addressing SSI, individuals must consider factors beyond scientific evidence, including social, economic, ethical, and political dimensions [8]. In SSI, students develop (a) a deeper understanding of content, (b) enhanced argumentation and decision-making skills, (c) reflection on social and ethical issues, and (d) self-efficacy, all of which contribute to cultivating a competitive, principled workforce [9], [10]. We believe this framework helped us develop a drone-centric curriculum that integrates the ethical and social issues surrounding drone technology.

Module-Based Approach

To effectively integrate socio-scientific issues with essential CS and ethics content, we developed a module-based approach featuring four modules, each guided by a driving question to foster student inquiry. For instance, one question, "How can we use drone technology to create positive impacts on people's lives?" encourages students to examine both the benefits and challenges of drone technology, addressing ethical dilemmas that arise in real-world applications. Students explored topics such as federal drone laws, the *Sky-of-Privacy-Things* (SoPT), cybersecurity, privacy, and ethical issues. They also participated in online group discussions (e.g., What specific programming techniques can be used to prevent and overcome the privacy and security challenges associated with drone technology?), programming projects, simulation analyses, and class discussions on visualization tools. In addition to lectures, students participated in inquiry-based learning through assessments outside of class.

Assessment Methods

The course used three assessment types: course-based, module-based, and self-assessments. Course-based assessments included quizzes, a midterm, and a final exam, evaluating students' understanding of cyber-aerial computing concepts, ethics, laws, and drone regulations. Four module-based assessments involved online group discussions and SSI-driven projects, with each module featuring one discussion and a corresponding project. These assessments fostered student inquiry, enabling them to explore ethical and social issues related to drones and apply their CS and programming skills to real-world challenges. Discussions facilitated collaborative reflection, serving as scaffolding for individual SSI-driven projects, which acted as summative assessments for each module. Students submitted four project reports, including simulated programming outcomes and responses to ethical questions. Self-assessments consisted of pre- and post-surveys measuring ethical awareness and behavioral intentions using a scale based on ethics education literature (see Appendix for examples).

Summary of Findings

We employed various data analysis methods to evaluate the effectiveness of the course in enhancing students' drone-centric CS knowledge and ethical awareness. Descriptive statistics were utilized to analyze quiz and exam results, while survey responses were examined using descriptive statistics for close-ended items and content analysis for open-ended responses. Additional analyses are ongoing as we process and manage the large volume of data sets.

Student Learning Outcomes

On average, students (N = 44) earned 38.91 points (*SD* = 2.17) out of 40 on the projects. This score corresponds to 97% of the total project points. For the exams, the average score was 21.95 points (*SD* = 3.31), equal to 73% of the total 30 points. The frequency distributions (number of students) of the assessment scores (% of total points) are shown in the figures below. These data, along with other assignment grades (e.g., online discussions) and the final letter grades (A = 20; A- = 11; B = 11; B- = 2), indicate that all students (100%) met the expected learning outcomes by passing the course with a grade higher than C (70% or more of the total course points).

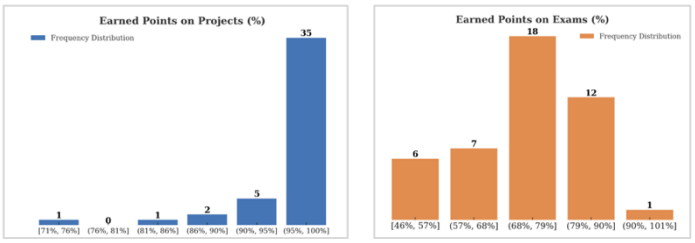

Figure 1: Student Learning Outcomes

However, given the highly skewed distribution of the SSI-driven project scores, we may consider modifying the scoring rubrics to improve the discriminating power of this assessment. This adjustment will help better differentiate between varying levels of student performance.

Ethics and Computer Science Perceptions

Forty-one students completed both the pre- and post-surveys. As shown in the figure below, students demonstrated improvements in every domain of ethics perceptions. The increases in *ethical awareness* ($p < .05$, Cohen's $d = 0.33$), *moral obligation* ($p < .001$, Cohen's $d = 0.58$), and *perceived behavioral control* ($p < .01$, Cohen's $d = 0.45$) were statistically significant. In addition, students showed increased, positive perceptions in CS ethics, cybersecurity self-efficacy, and career aspirations in cybersecurity, although these improvements were small (d = 0.07-0.09) and non-significant ($p > .05$).

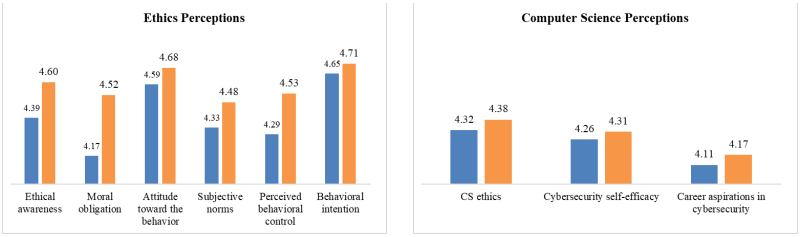

Figure 2: Student Ethics and Computer Science Perceptions

The analysis of students' open-ended responses revealed shifts in their perceptions of ethics in drone technology. While their initial understanding was primarily focused on cybersecurity concerns, they later expanded their perspectives to include broader ethical issues, such as "privacy invasions and other privacy-related issues" (Comment 1). Moreover, many reported that they began considering ethical implications before coding (e.g., Comment 16, 26, 37). They also recognized the importance of employing security techniques, such as "random waypoint mobility to prevent attackers from gleaning useful information… and to protect users" (Comment 16).

Strengths and Areas of Improvement

In the post-survey, students noted strengths and areas of improvement for this course. Strengths included (a) in-depth and diverse curriculum, (b) effective teaching and course management, (c) practical and ethical focus, and (d) supportive learning environment. For example, students found the focus on real-world situations and ethical issues related to drones in the curriculum particularly beneficial, providing a complete understanding of the subject (Comments 2, 23, 35). A student commented: "Originally the only ethical concern I considered was drone usage for stalking. However, after this course, it truly broadened my scope of some of the ethics behind cyber-aerial computing" (Comment 13). They also found the SSI-driven projects as a strength of this course, helping to apply theoretical knowledge in practical scenarios (Comments 14, 33, 40). Areas of improvement included (a) increased practical and hands-on experience, (b) improved project focus and structure, (c) enhanced course materials and lecture notes, and (d) additional topics with depth. While many enjoyed the discussions on ethical and social issues, there were several students who felt that there was too much focus on ethics and privacy, suggesting a reduction in this area in favor of more technical content (Comments 18, 19, 22).

Discussion

Our findings suggest that integrating SSI elements effectively fostered students' development of ethical perspectives on emerging issues related to drone technology. Students developed ethical awareness when engaging with driving questions and real-world problems that integrated ethics into technical discussions. Some had also begun emphasizing the societal and practical consequences of their technical decisions. This indicates that addressing both practical and ethical topics alongside emerging technologies within the SSI curriculum provides a holistic framework. Embedding ethics into SoPT education through real-world drone applications encouraged students to think beyond technical proficiency, fostering a deeper understanding of ethical responsibilities in their practice. Perhaps this approach made ethical issues more tangible for those who are interested in the topic and relevant careers, aligning well with career readiness.

While many students appreciate the ethical focus, some feedback suggests that an overemphasis on ethics could detract from technical content. Thus, maintaining a balance through incorporating ethics into hands-on technical activities becomes critical, allowing students to simultaneously develop ethical awareness and technical expertise.

Implications for Future Research

The new curriculum serves as a model for integrating cybersecurity and privacy into engineering education and offers a framework adaptable to other disciplines, addressing security and privacy from diverse perspectives. Future research may further explore the role of SSI framework in cyber-aerial computing education and its longitudinal impact on ethical decision making. Future studies could also measure the framework's impact on students' problem-solving abilities, especially when dealing with even more complex, real-world security or privacy challenges.

Acknowledgement

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Appendix

S. Shin, J. Lee, S. Lim, and S. Shin. "Draft of ethical motivation and behavioral intention survey in engineering education," *American Society for Engineering Education Annual Conference*, June 22-25, 2025, Montreal, Canada, 2025.

Sample Survey Items for Ethical Motivation and Behavioral Intention

We used a 6-point Likert scale (including "Don't Know" as an option) for this survey. The survey is currently undergoing a validation process and will be documented in a validation study.

I am confident in my ability to recognize ethical issues when faced with problems.
I am confident in my ability to apply ethical standards for reasoning through problems.
I will continue making ethical decisions in the future.
I will try to act ethically during my engineering major.
I feel motivated to behave ethically when my actions are supported by people important to me.
I feel obligated to prioritize moral values over other values.
I prioritize moral values over other considerations when making decisions.
I am confident in my ability to behave ethically in various situations.
I am confident in my ability to act ethically when formulating solutions to problems.

Sample Survey Items for Computer Science Perceptions

We used a 6-point Likert scale (including "Don't Know" as an option) for this survey. We modified the existing validated survey items in the literature.

It is important to acquire professional ethics relevant to my future career.
Learning ethics in computer science is equally important as mastering the technical content of computer science.
Acquiring expertise in drone-centric computing is essential for my future career.
Drone-centric computing is interesting to me.
I am curious about drone-centric cybersecurity.
I am confident I can learn programming for drone operations.
I am confident I can do well on drone-centric tests in this course.
I am confident I can do well on drone-centric projects in this course.
I am confident I can quickly learn cybersecurity measures for drone operations.
I want to pursue a career in cybersecurity.
Knowing ethics relevant to cybersecurity will provide me with a career advantage.

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