

Ethics Education in Undergraduate Computer Science Programs in the United States

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Analysis of Ethics Education in Undergraduate Computer Science Programs in the United States

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Introduction

We have witnessed the emergence of new technologies that solve problems and make our lives better. The use of new technologies has dramatically changed social conditions, and its rapid rate is causing new problems and issues that test our values [1]. The invention of email has made it possible for instant communication all over the world, but it has also opened the door for phishing scams to steal financial information. The World Wide Web provides access to a wealth of information on all kinds of topics, but it also exposes children to inappropriate content like pornographic websites. It gives us a good reason why we need to make ethical decisions, weighing the benefits and potential harms associated with the use of new technology.

As many issues in computer science depend on persona and identity, it is critical that every individual working in this area have an acceptable level of ethical awareness and sensitivity, and they must be able to make an ethical decision whenever they face an issue [2]. To achieve this, we need to teach computer and information ethics to students from undergraduate programs, along with theories and technologies in computer sciences. Recent research shows us that ethics education improves students' ethical awareness and sensitivity as well as moral reasoning [3]–[4]. While many undergraduate computer science programs include ethics in their curriculum, the teaching methods, topics, target students, credit hours, and instructor expertise vary [5]–[8]. There is an urgent need for a comprehensive analysis of the status of ethics education in undergraduate computer science programs, but most of the available resources are outdated.

To address this need, in this paper, we create a hierarchy of ethics topics based on existing textbooks and conduct a survey of seventy undergraduate computer science programs in the United States. The results of the analysis are discussed, including the most and least covered topics, ethics as a standalone course, the levels of ethics courses, and whether ethics is a mandatory or optional course. Based on the findings, we discuss the current status of ethics education in undergraduate computer science.

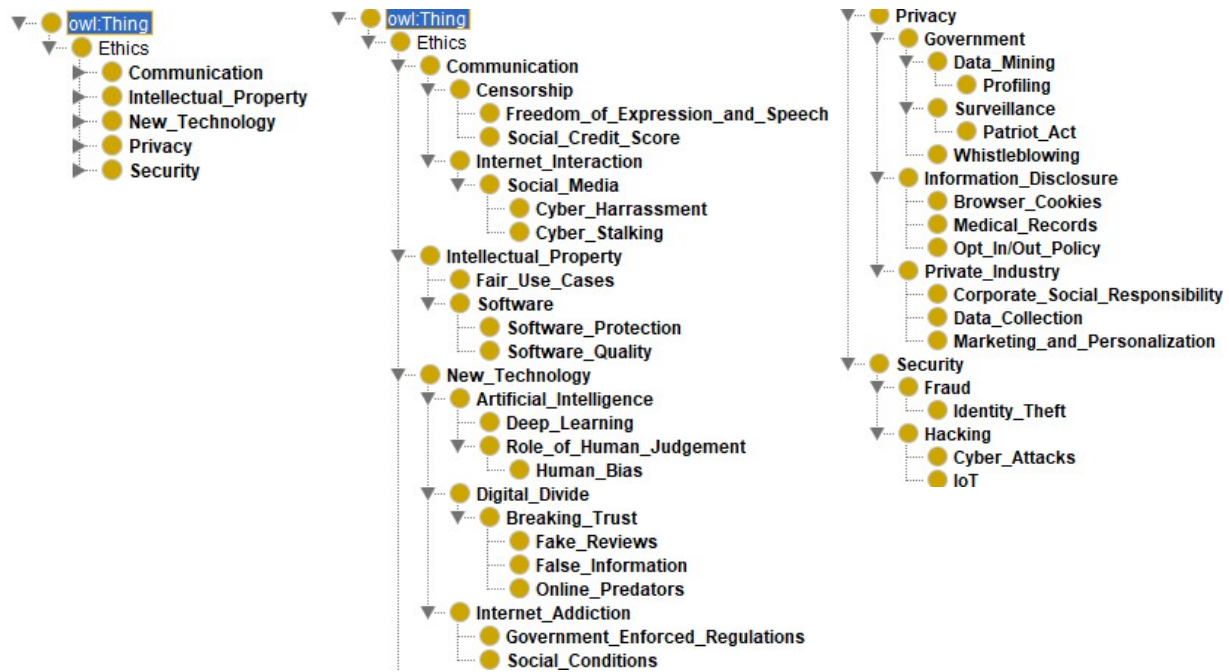
Topics that are covered in existing books on computing and information ethics

To analyze ethics topics that are currently covered in the undergraduate computer science programs, we first identified the top 10 research papers that were published between 2000 and 2022 with high citation numbers on *Google Scholar* and the top 5 best-selling books on computing and information ethics with a large number of reviews and high customer ratings at *Amazon* and *Barnes & Noble* [9]–[13]. Second, we extracted ethics topics through lexical analysis. Lexical analysis [14] is the first step of natural language processing that divides a text into words and looks for morphemes, the smallest unit of a word. For each paper and textbook, we ran lexical analysis on their abstract and table of contents and collected meaningful nouns as

ethics topics. Third, we selected five of the most popular topics that occur most frequently across papers and books. Note that we selected the top five due to the gap between the frequencies of the fifth and sixth topics. We defined those five topics, which include *Communication*, *Intellectual Property*, *New Technology*, *Privacy* and *Security*, as high-level topics, and then extracted all relevant topics for each high-level one by using syntactic analysis [14] which finds relationships between words.

Hierarchy of ethics topics

According to the result of the lexical and syntactic analysis of books and research papers, we created an ontology to represent the structured relationships between topics on ethics in computer science, as shown in Figure 1. Ontology is an explicit and well-structured specification of shared knowledge, and it is a proper way to define topics and relationships between them. The proposed ontology is written in OWL 2 [15], an ontology language that provides classes, properties, individuals, and data values.



a) High-level topics of Ethics Education b) Sub-topics of *Communication*, *Intellectual Property*, and *New Technology* Topics c) Sub-topics of *Privacy* and *Security* Topics

Figure 1. Hierarchy of Ethics Topics in Computer Science Education

Analysis of existing undergraduate computer science programs

To check the status of undergraduate education on ethics in computer science, we have researched the top 70 programs in the United States according to the US News ranking [16]. Note that there are one or more programs in a certain rank. Therefore, the top 70 programs are aligned from the top 1 to 60. For each program, we have searched for a course that covers one or more ethics topics by analyzing course descriptions and syllabi. In the case that course information was not available online, we contacted instructors directly to collect data.

We found that 59 of the 70 programs teach ethics in their curriculum, while 11 do not. In those 59 programs, we found 77 courses that include 30 ethics courses and 47 ethics-related courses that cover ethics topics partially. The detailed course and topic analysis are provided below.

Program with Ethics VS Program without Ethics	Program Count	Type of Courses in the Programs with Ethics	Course Count	Proportion of Undergraduate CS programs
Programs with Ethics	59	Ethics courses	30 (38.96%)	32.84%
		Ethics-related courses	47 (61.04%)	51.45%
		Total	77	
Programs without Ethics	11			15.71%
Total	70			100%

Table 1. The Proportion of Undergraduate CS Programs

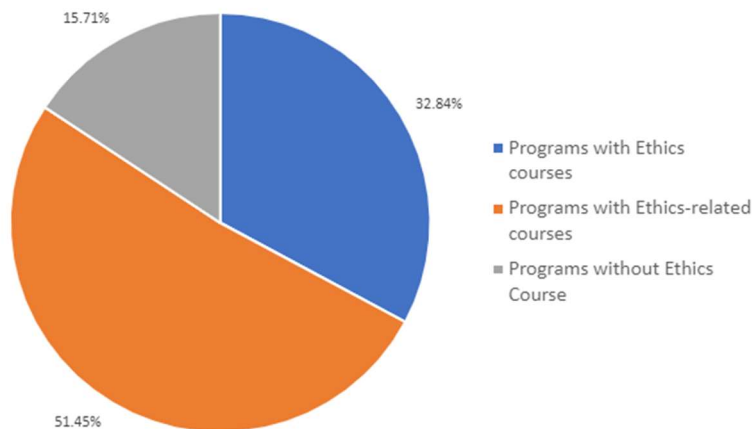


Figure 2. Analysis of the Top 70 Undergraduate Computer Science Programs

Analysis of ethics courses

In our survey, we found 30 courses that solely focus on ethics. Among the 30 courses, 14 are in the ABET-accredited programs, and 16 are in the programs without any accreditation (see Table 2 and Figure 3). We have checked the levels of those courses. Most of the ethics courses are upper-level courses. There are 14 junior and 10 senior courses, whereas there are only 6 freshman and 2 sophomore courses (see Table 3 and Figure 4). Note that two courses are defined as freshman and sophomore courses. We counted those courses twice, and that is why the total number of courses is 32. In many undergraduate programs, ethics courses are not required. 19 ethics courses are not required for a program, while only 11 courses are required (see Table 4 and Figure 5). Regarding the U.S. News ranking [16], the programs that have ethics courses are distributed as shown in Table 5 (see Table 5 and Figure 6). Interestingly, the programs in the top 10 and those between the top 51 and 60 have many ethics courses, while programs between the top 21 and 30 have only two ethics courses.

Accredited VS Non-accredited Program	Course Count
Ethics courses in accredited programs	14
Ethics courses in non-accredited programs	46
Total	30

Table 2. The Proportion of Accredited vs. Non-accredited Programs that have Ethics Courses

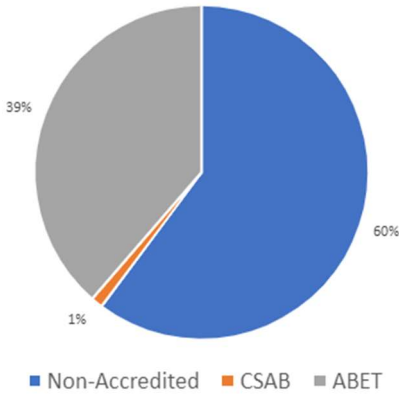


Figure 3. Analysis of Accredited vs. Non-accredited Programs that have Ethics Courses

Required VS Non-required Courses	Course Count
Required courses	11
Non-required courses	19
Total	30

Table 4. The Proportion of the Required vs. Non-required Courses of Ethics courses

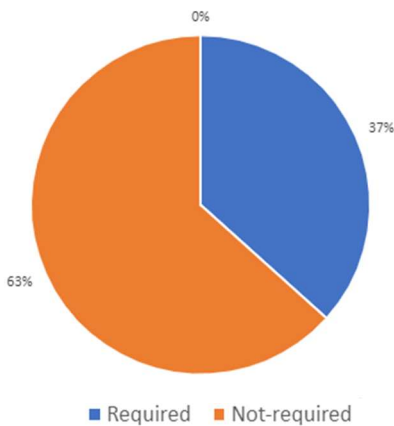


Figure 5. Analysis of the Required vs. Non-required Courses

Course Level	Course Count
Freshman courses	6*
Sophomore courses	2*
Junior courses	14
Senior courses	10
Total	32

Table 3. The Proportion of the Levels of Ethics Courses (* : Two courses are freshman/sophomore courses)

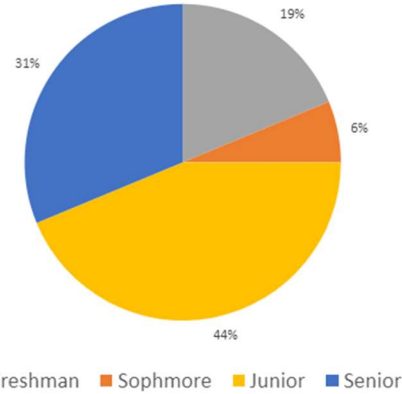


Figure 4. Analysis of the Levels of Ethics Courses

Program Rank	Course Count
Top 1-10	8
Top 11-20	4
Top 21-30	2
Top 31-40	5
Top 41-50	3
Top 51-60	8
Total	30

Table 5. The Proportion of Programs' Rankings

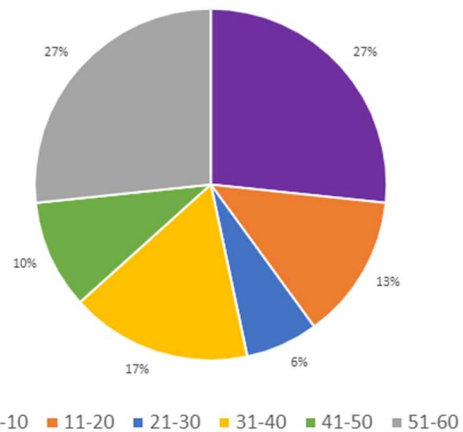


Figure 6. Analysis of Programs' Rankings

Analysis of ethics-related courses

As you have seen in Figure 1, there are more courses that do not solely focus on ethics but cover some ethics topics as subtopics. We found 47 ethics-related courses, which include 18 courses in the ABET-accredited programs and 29 courses in the programs without accreditation (see Table 6 and Figure 7). Similar to the ethics courses, most ethics-related courses are junior and senior courses, with only a few sophomore courses (see Table 7 and Figure 8). Unlike ethics courses, which have a small difference between required and non-required courses, the majority of ethics-related courses are non-required (38 out of 47), with only 7 required (see Table 8 and Figure 9). Like ethics courses, more than half of the 47 courses are taught in the top 1-10 and 51-60 programs (see Table 9 and Figure 10). *Ethics and Society* and *Introduction* courses are the most frequently used to cover ethics topics in undergraduate programs, followed by *Artificial Intelligence* and *Policies and Law* courses (see Table 10). As the ethics-related courses teach ethics as a subtopic, we researched which topics are mostly covered in those courses. The results show that the most frequently taught topic is the general introduction to *Ethics*, with *New Technology* and *Privacy* coming in second and third, respectively (see Table 11).

Accredited VS Non-accredited Program	Course Count
Ethics-related courses in accredited programs	18
Ethics-related courses in non-accredited programs	29
Total	47

Course Level	Course Count
Freshman courses	12
Sophomore courses	6
Junior courses	17
Senior courses	12
Total	47

Table 6. The Proportion of Accredited vs. Non-accredited Programs that have Ethics-related Courses

Table 7. The Proportion of the Levels of Ethics-related Courses

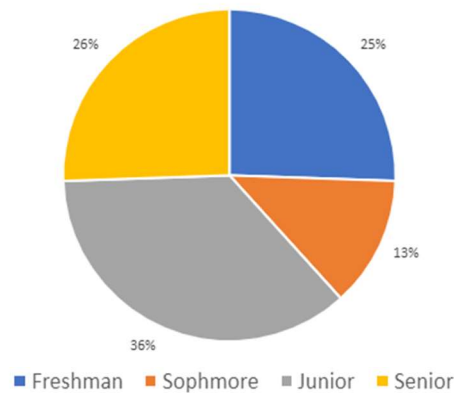
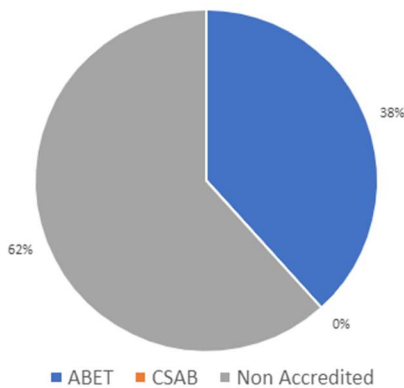


Figure 7. Analysis of Accredited vs. Non-accredited Programs that have Ethics-related Courses

Figure 8. Analysis of the Levels of Ethics-related Courses

Required VS Non-required Course	Course Count
Required courses	7
Non-required courses	38
Not specified	2
Total	47

Table 8. The Proportion of the Required vs. Non-required Ethics-related Courses

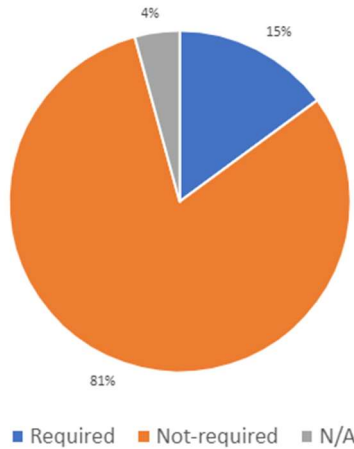


Figure 9. Analysis of the Required vs. Non-required Ethics-related Courses

Rank (Count)	Category of Ethics-Related Courses
1 (10)	Ethics and Society, Introduction
2 (8)	Artificial Intelligence, Policies and Law
3 (4)	Computer Science
4 (3)	Network
5 (1)	Privacy, History of Technology

Table 10. Ranks of Ethics-related Courses

Program Rank	Course Count
Top 1-10	11
Top 11-20	3
Top 21-30	7
Top 31-40	9
Top 41-50	3
Top 51-60	14
Total	47

Table 9. The Proportion of Rankings of Programs that have Ethics-related Courses

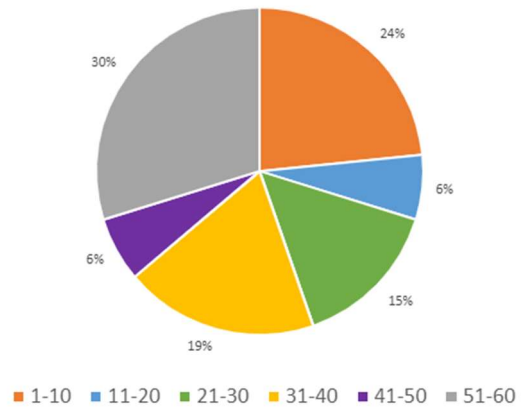


Figure 10. Analysis of Rankings of Programs that have Ethics-related Courses

Rank (Count)	Ethics Topic
1 (47)	Ethics
2 (26)	New Technology
3 (19)	Privacy

Table 11. Ranks of Topics covered in the Ethics-related Courses

Ethics topics covered in undergraduate CS programs

To determine how effectively existing courses cover ethics topics, we counted the frequency of topics that appear in course syllabi and assignments in all types of ethics courses. Note that we counted a topic only once in a course even though that topic has appeared multiple times. In Table 12, you can see the rank and the total count for each topic in the current ethics courses. As you can see in the table, generic topics, which include *Ethics*, *New technology*, *Privacy*, and

Artificial Intelligence, are the most frequently covered, while specific and detailed topics like *Fake Reviews*, *Identity Theft*, *Cyber Harassment*, and *Fraud*, are less frequently covered. Please note that we counted topics from the syllabi and assignment descriptions only.

Rank (Freq.)	Topic	Rank (Freq.)	Topic	Rank (Freq.)	Topic
1 (198)	Ethics	9 (17)	Private Industry	22 (7)	Social Media
2 (61)	New Technology	10 (16)	Role of Human Judgement	23 (6)	Freedom of Expression & Speech, Software Protection, Data Mining
3 (60)	Privacy	11 (15)	Hacking	26 (5)	Social Conditions, Fair Use Cases
4 (37)	Artificial Intelligence	12 (14)	Information Disclosure	28 (4)	Deep Learning, Whistleblowing, Corporate Social Responsibility
5 (30)	Intellectual Property	13 (12)	Software	31 (3)	Medical Records, IoT
6 (21)	Communication, Security	14 (11)	Censorship	33 (2)	Breaking Trust, False Information, Government Enforced Regulations
8 (20)	Government	15 (9)	Digital Divide, Internet Interaction	36 (1)	Cyber Harassment, Software Quality, Patriot Act, Profiling, Opt in/out policy, Marketing and Personalization, Fraud
		17 (8)	Human Bias, Internet Addiction, Surveillance, Data Collection, Cyber Attacks	Not covered (0)	Fake Reviews, Online Predators, Social Credit Score, Cyber Stalking, Browser Cookies, Identity Theft

Table 12. Ranks of Ethics Topics covered in the Top 70 Undergraduate CS Programs

According to the frequencies of topics in Table 12, we categorized topics into four groups: *Group 1* contains the most popular topics ranked 1–8; *Group 2* contains popular topics ranked 9–17; *Group 3* contains unpopular topics ranked 22–36; and *Group 4* contains uncovered topics. Using the categorization, we visualized the topics’ popularity using indexed colors, as shown in Figure 11. As we can see in Figure 13, all the high-level topics, which include *Communication*, *Intellectual Property*, *New Technology*, *Privacy*, and *Security*, belong to *Group 1*. It means that the most significant concepts are covered in many programs. However, it seems that technology-related topics like *Software Protection and Quality*, *Deep Learning*, *Data Mining*, *Browser Cookies*, *Identity Theft*, and *IoT*, are addressed less.

Conclusion

In the past decades, we have recognized the importance of ethics education in computer science and tried to find essential topics to be covered and the most effective teaching methods and pedagogies. To discuss further improvement in ethics education, we first need to know where we are. Towards this goal, in this paper, we proposed an ontology for ethics education in computer science using the OWL 2 web ontology language and presented key aspects of ethics education based on analysis of the top 70 undergraduate computer science programs in the United States. We believe that the outcomes of this research will give us meaningful insights into current undergraduate programs in computer science and provide guidelines for future research on ethics education.

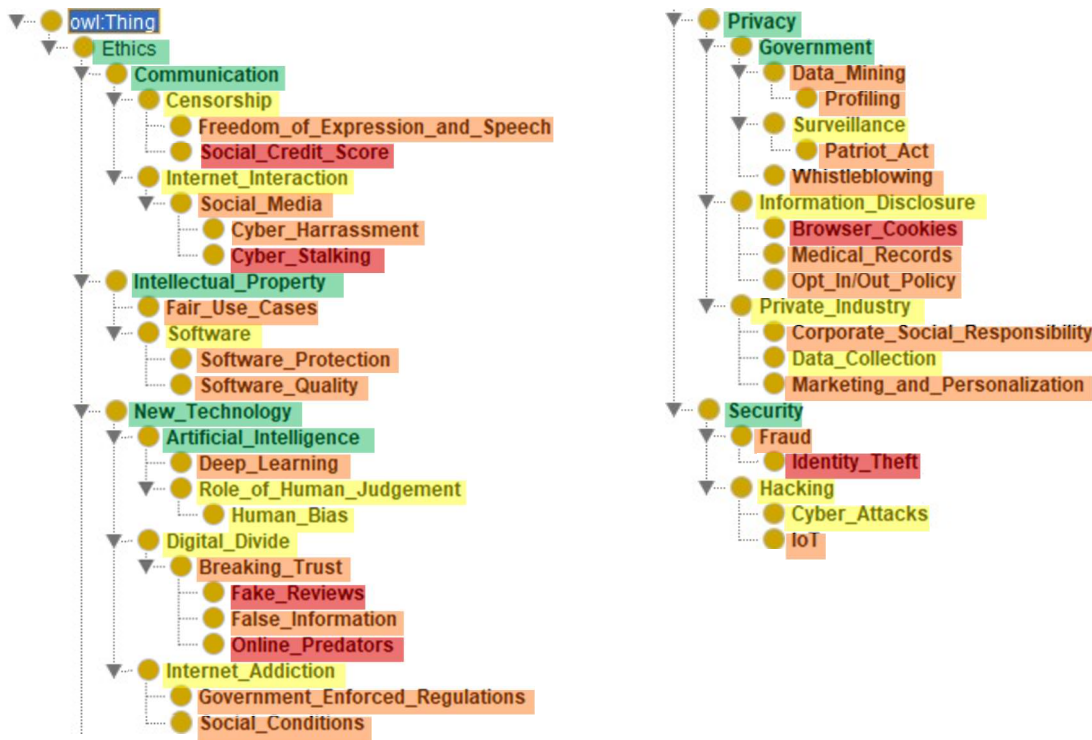


Figure 11. Color-indexed Hierarchy of Ethics Topics
 (Green: Top 1-8, Yellow: Top 9-17, Orange: Top 22-36, Red: Uncovered Topics)

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