Ethical thinking and programming

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There is an increasing prevalence of programming in mathematics education. In this paper, we focus on ethical aspects of programming by first presenting a literature review. Three interrelated topics are identified in the review: reasons to include ethics in programming, code literacy, and facilitating ethical thinking. These three topics are then used to reflect on ethical thinking and programming in three tasks developed by a lower secondary school teacher. We argue that the context of programming tasks such as climate change, sustainability, and decision-making of self-driving cars, can facilitate students' ethical thinking alongside their learning of how to program.

Introduction

Programming is increasingly influencing society in invisible ways: what kind of information and advertisements people receive on social media, what people find through search engines, who get treated in hospitals or gain access to vaccines, terms of insurances, access to loans, etc. O'Neil (2016) denoted mathematics-based algorithms as weapons of math destruction if they contribute to destructive decisions, for example, increasing inequality in society through biased mathematisation of a problem. She further argued that this threatens democracy and emphasised that transparency and disclosure are crucial because the invisible algorithms steer human behaviour favouring certain interests. Programming and algorithms do not possess any morality; humans embed values into the algorithms. Human choices in mathematical modelling and programming affect whether values such as profit should trump fairness. O'Neill highlighted that if we treat mathematical models, data, and algorithms as neutral, we "abdicate our responsibility", and she argued for bringing "fairness and accountability to the age of data" (p. 218).

Artificial Intelligence (AI), where machines are programmed to learn, think, and act like humans, is of particular concern because decisions may be based on machine learning, without humans having the last say. Examples of related public debates include Tay – the hateful Microsoft bot, self-driving cars, and warfare based on AI, where one discussion concerns who is responsible if something goes wrong. Rhim et al. (2020) compared Korean and Canadian respondents' preferences on what ethical principles should be guiding for self-

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driving cars in imagined car crashes. They concluded that there are some cultural differences in ethical reasoning, as Canadian repondents tended to favour decisions minimising casualties, while Korean favoured decisions that followed traffic rules. Buolamwini (2016) emphasised that due to algorithmic biases and the social implications and harms that AI can cause, an awareness of "who codes", "how we code", and "why we code" is crucial. Colman et al. (2018) underlined that since 1980, "more and more problems from more and more diverse fields are being treated as "computable" problems; which means they are being tackled in algorithmic manner" (p. 8), even if the problems are wicked or unsolvable. As critical citizens, it becomes essential to question whether all problems are computable and how results need to be treated with care.

With these concerns in mind, it is important to remember the wonders digital algorithms and AI have helped achieve, for example, improved medical care, smartphones, and a range of other mathematics and programming-based technologies. However, many wonders are accompanied by concerns and constitute challenging dilemmas. These may be consequences of digital technologies applied in new contexts, for instance, face recognition applied in surveillance of citizens and data collected by Google and Facebook. It can also be dilemmas that are part of the technology itself, such as the question of who is responsible for fatal accidents caused by self-driving cars. AI is often accused of including black box decisions, i.e., that it is impossible to know what exactly led to the specific decision. This implies a lack of transparency and thereby, uncertainty associated with the quality of decisions (NENT, 2020).

The development of digital technology has long shown a mismatch between who gains from it and who are burdened (e.g., technology contributing to climate change). Digital technology impacts individuals (e.g., smartphones increase individuals' possibilities, but data on personal searches and likes are collected and traded) and society (e.g., how a good life and a good society is understood and the easy spread of fake news). Taken together, the development of programming and digital technology constitute a range of ethical dilemmas connected to its applications, power relations, and personal and societal implications.

According to Balanskat et al. (2017), computational thinking, programming, or coding was included in at least 20 national curriculums in Europe in 2017. This is likely to increase because of the EU's policy document *Digital agenda for Europa* (http://ec.europa.eu/digital-agenda), and how programming is becoming more evident in national policy documents (Bocconi et al., 2018). Programming has become a significant part of the Norwegian curriculum in mathematics (MER, 2020). It is also included in natural science, music, arts and design, and as an elective subject in primary and secondary school. An aim of the elective subject is to develop ethical awareness and critical thinking regarding processes and uses of technology. Relatedly, an aim of the mathematics curriculum is to develop an understanding of technology that can help students make "responsible life choices" (MER, 2019, p. 3). Based on these guidelines from the national curriculum, the focus in this paper on technology, programming and ethics can be regarded as an important part of mathematics education.

Investigating ethical thinking when programming is a rather new research field within mathematics education. In this paper, we start exploring what such ethical thinking might be. We do this by first conducting a literature review to identify key topics in the research that addresses ethical thinking and programming in education. Secondly, we present three programming tasks and discuss them in light of the identified topics in the review.

Clarification of concepts

Computational thinking is the overarching concept in which programming and algorithms constitute key components. Computational thinking involves systematic steps to solve problems and find solutions, and programming is often required to execute these solutions (Morris et al., 2017). Balanskat and Engelhardt (2015) described programming as "the process of developing and implementing various sets of instructions to enable a computer to perform a certain task, solve problems, and provide human interactivity" (p. 6). Normally, such instruction sets are called algorithms, which Colman et al. (2018) defined as instructive steps "used to organise, calculate, control, shape, and sometimes predict outcomes" (p. 8). These steps are expressed through a code, understood as a computer programme's digital language, which carries out the algorithms in practice (Nygård, 2018). Bocconi et al. (2018) denoted computational thinking as "a thought process entailed in designing solutions that can be executed by a computer, a human, or a combination of both" (p. 7). In this paper, we add ethical thinking to this thought process.

Ethical thinking can be described as an "assemblage of skills and cognitive processes related to determining how to act ethically and how to think through ethical choices and scenarios" (Schrier, 2015, p. 394). Ethical dilemmas involve situations where there is no obvious choice between two or more conflicting scenarios. For instance, the programming of self-driving cars need to implement decision-making on who to hit in case of an inevitable accident (Seoane-Pardo, 2016, 2018; Rhim et al., 2020). Introducing students to ethical decision-making while learning programming can help prepare them for these situations. Ethical awareness is then relevant and can include understanding moral dilemmas, identifying perspectives, interpretation of situations, and imagining causes and effects of decisions (Schrier, 2015).

Three ethical approaches are of particular relevance in ethical decision-making. *Virtue ethics* involves moral characteristics and intention behind actions, *deontological ethics* deals with the rules guiding the moral evaluation of the action, while *consequential ethics* emphasises the consequences of actions (Hursthouse & Pettigrove, 2016). Decision-making models can be of value when focusing on ethical thinking in educational contexts. Schrier (2015) described identifying and being aware of ethical issues, of evaluation and judging, of focusing on specific goals, and of implementing action as important characteristics of how to deal with the process of ethical considerations. These elements are relevant to include when teachers facilitate programming with students.

Methods

A literature review was conducted to gain insight into research on ethical thinking and programming in education. Two databases were used, Eric and Scopus. The search words were coding, programming, ethic*, ethical issue, ethical concerns, ethical dilemmas, education, school, learning, teaching, classroom, and education system. The search was limited to full-text articles from 2010–2020. A total of 255 texts were identified, but the majority of these were not relevant (e.g., the words *coding* or *programming* did not refer to computer programming). Ultimately, 25 of the 255 articles were scrutinized, and several of these are referred to in this paper. A more comprehensive literature review could have included other search words, other search engines, conference proceedings, and books. We categorised the included literature in terms of three identified topics: reasons to include ethics in education on programming, code literacy and ethical thinking, and facilitating ethical thinking.

We apply these topics when discussing three tasks developed by Max, a mathematics, science, and programming teacher in lower-secondary school. She developed several tasks for an elective subject, programming. The three tasks presented in this paper are chosen because they somehow involve ethical aspects. The first task involves the ethics of self-driving cars. The second task concerns how drones can monitor and be a tool to counteract climate change. The third task is on how drones and programming can help create a better future. Empirical data from her classroom are not available yet, but that does not displace the purpose of the discussion of the tasks in this paper: to investigate potentials for facilitating students' ethical thinking.

Ethical thinking and programming in education research

In the following, we present the three core topics identified in the literature review.

Topic 1: Reasons to include ethics in education on programming

Colman et al. (2018) and Dufva and Dufva (2016) argued that ethical reflections should be included when coding is part of teaching. In line with O'Neil (2016), Dufva and Dufva (2016) stressed that coding is not value-free and reflects both "conscious and subliminal values of the programmer" (p. 98). They claimed that teaching programming is often restricted to mechanical learning and suggested that education should include discussions of the ramifications of technologies. They further argued that programming could be seen as a "complex man-made tool for shaping the world" (p. 107), changing our behaviour and practices. This resembles Skovsmose's (1994) concept of the formatting power of mathematics, which denotes the role mathematics has in shaping society, often in invisible ways. Programming and mathematics often form the basis of technological structures, processes, and innovations. Ravn and Skovsmose (2019) highlighted how mathematics-based actions, often formed through technology that incorporates mathematics, should be ethically sound. They use Google's search engines as an example of a mathematics driven technology

where mathematical operations and algorithms are included in a complex network of operations that needs ethical considerations.

Colman et al. (2018) emphasised the ethical challenge connected to big data. Digital citizens are users of Internet and social media, such as Google and Twitter, and at the same time, providers of data that influence the same citizens through invisible algorithms developed to ensure profit. Ethics and societal implications should, according to Burton et al. (2017) and Rodríguez García et al. (2020), be key elements in computer engineering courses and school subjects involving AI.

Kules (2016, 2018) reasoned that ethical issues like diversity and equity should be addressed when learning programming. He described a curriculum for helping (graduate and undergraduate) students "recognize, analyze and take action when they encounter these issues" (2018, p. 31). The curriculum was part of a course teaching JavaScript and Python and constituted learning outcomes targeting to situate programming in the broader social structures. This was facilitated by students reading relevant literature and by weekly reflective discussions concerning topics such as coding for the social good and forms of inequity, for instance how algorithms determine prison sentences and how search engines reinforce existing social and cultural biases on attitudes towards women. The findings showed that students demonstrated abilities to identify and examine ethical issues in programming. This explicit focus on ethical issues associated with programming brings an awareness to programming as a non-neutral activity that involves ways of impacting society.

Reasons for adding ethics to learning programming thus include understanding that programming is not necessarily value-free, that digital technology is shaping the world, also in ways that are unfair and destructive, and that big data and artificial intelligence are particular topics that require ethical reflection.

Topic 2: Code literacy and ethical thinking

To participate in discussions on ethics, Dufva and Dufva (2016) proposed code literacy to be recognised as "understanding of the code and its intentions and context" (p. 98). They connect these discussions to Freire's (2014) ideas of "forming rather than training students" (p. 107), as training students in coding is not enough to form a critical mindset of digital technologies' potential implications. Dufva and Dufva (2016) suggested that education and code literacy should include the following: *learning a programming language*, *understanding the structure and intelligence of code, and how code can solve problems* (through being a transformative tool, making the world (supposedly) a better place). Further, *placing coding in its cultural context* (how mindsets, ideologies and trends influence the code), *understanding ways code affects society and individuals* (through game obsession or hierarchical systems that affect people's everyday lives, e.g., through the Internet and political (mis)uses of code), and *identifying power issues involved in coding* (e.g., Google's personalised search results, possible misuse of data for surveillance purposes, hacking damages, but also consumer power and other possibilities for changes). Lastly, *learning to use code as a way of self-*

expression (by deconstruction main concepts or exercise creativity). The purposes thus include both basic principles and logics of coding, as well as the more intertwined ethical issues involving coding and individuals/society. Code literacy is therefore, according to Dufva and Dufva, about understanding and living in a digitalised world.

Summing up, ethical reflection and ethical decision-making is argued to be part of code literacy. Coding can thus facilitate ethical awareness, reasoning, and reflection related to ethical decision-making in real-world problems, in line with Schrier's (2015) education goals for ethical thinking through computer games.

Topic 3: Facilitating ethical thinking

Several frameworks for ethical thinking related to education and programming have been highlighted. Burton et al. (2017) suggested that students should learn about ethical theories to apply them as tools for reflecting on case studies. They showed how deontological ethics ("What are the right rules"), utilitarianism ("What is the greatest possible good for the greatest number?"), and virtue ethics ("who should I be?") provide different questions and, thus, different modes of ethical thinking relevant to the problem at hand (p. 26). They suggested a mix of the three approaches when deciding how a robot should behave or how to target the audience when advertising.

Ladwig and Schwieger (2020) suggested the following ethical decision-making model for graduate courses in computer programming: *describe possible ethical dilemmas, identify stakeholders, outline options on how stakeholders are affected, and make a decision.* They suggested, amongst others, that students discuss ethical perspectives regarding algorithms for self-driving cars concerning choices in a potential collision. Seoane-Pardo (2016, 2018) argued that ethics is an essential part of computational thinking. Seoane-Pardo's developed teaching and learning lessons on self-driving cars for students (age 14–16) on programming and ethical reflection. The lessons were developed to facilitate various ways of ethical thinking in decision-making: consequential approaches – minimising casualties, minimising own risk or minimising economic cost, deontological approach – protecting those who follow the rules, and non-deterministic approach – mimicking random behaviour (Seoane-Pardo, 2018). He noted that AI programming is too advanced for these students, but pointed to tools developed in Arduino and Scratch which are designed for students to program ethical decision-making situations with self-driving cars.

Estevez et al. (2019) showed how an AI workshop with high school students changed the students' perception of ethical issues. The workshop was about developing code and discussing AI properties and limitations. After the workshop, the students were less concerned about dangers presented in sci-fi movies and more concerned about AI regulations to prevent bad usage of data due to privacy and freedom perspectives.

Taken together, ethical thinking and learning can be facilitated through working with real-world problems while applying ethical theories, how decision options affect stakeholders differently, and drawing attention to ethical dilemmas.

Three programming tasks

We now turn to three programming tasks designed by a lower secondary teacher, Max. These are discussed in terms of potentials for ethical reflections, referring to findings in the literature presented above.

First task: Self-driving cars

As part of the task involving self-driving cars, Max made a pamphlet with some information. One of the paragraphs reads as follows:

> In the development of self-driving cars, systems and services must be developed. Programming is an important element to achieve this, but merely developing technology is not sufficient. Students must reflect on the possibilities and challenges this technology presents and take a stand on associated ethical issues.

It is stated that AI technology in self-driving cars includes both possibilities and ethical challenges. This implies that such AI technology is not value-free and is therefore a reason for including ethics in computational thinking, in line with Burton et al. (2017) and Rodríguez García et al. (2020). The task encourages reflections on ethical issues which later are connected to the programmer's role:

> Machines do not have ethics and morals; they do as they are programmed. If a self-driving car is in a situation where someone has to die, it must choose. How should we decide how it should act, and will we buy a car that is programmed to kill us?

The task suggests that the teacher understands code literacy as something more than just technical aspects, as it calls for ethical awareness and reasoning on decision making associated with a real-world problem, in line with Dufva and Dufva's understanding of code literacy (2016).

The task facilitates ethical thinking through bringing attention to choices of a self-driving car, and that a choice may have stakeholder consequences. It signifies an ethical dilemma concerning who must die in a specific situation. If a driver in a regular car encounters an accident, decisions are often based on intuitive reactions. In a self-driving car, the decision on whether to crash into, say, a pedestrian or a car, is taken in advance through decisions in the code. Reflecting on these ethical dilemmas is what Ladwig and Schwieger (2020) and Seoane-Pardo (2016, 2018) promote. This implies that various ethics theories are relevant for drawing attention to ethical questions such as what the dilemmas are, who the stakeholders are, what are the decision options, and what makes machines different from people in decision-making situations. The task does not explicitly address all these aspects, but it can be done by the teacher or students. Attention can be drawn to different stakeholders: the driver, others in the traffic, people involved in the car production, and authorities responsible for traffic safety. Decisions taken in the coding will affect these stakeholders differently. For instance, governments aiming to reduce traffic deaths may prefer the choice of minimum deaths, while it may pay off for the producer to let the buyer of the car choose preferred algorithms.

Second and third task: Sustainability and climate change

> *Task 2:* Have you ever wondered how we can use drones to stop climate change? Use your creative skills to find a solution where drones can be used for this purpose. Present creative suggestions on solutions by programming a mini-drone so that it conducts an operation that can help stop global warming.
> *Task 3*: Mother Teresa says that sometimes we think that what we do is just a drop in the ocean. But the ocean would be smaller without that drop. Create a product that can be programmed either block or text-based, and which can help make the world a better place to live for children in the future. Keywords: sustainability, energy, the sea, entrepreneurship, farming, technology, etc.

In these extracts from two different tasks, the students are asked to contribute to make the world a better place for future children. Preventing global warming and making the world a better place are ethical topics in themselves and give reason for ethical reflections. The tasks suggest that drones can have an essential role in monitoring climate change indicators in remote places. They could partly replace fossil transportation, plant seeds in agriculture, replant forests after deforestation and in post-fire areas, etc., and directly contribute to potentially less CO_2 emissions. This implies that ethics can be embedded in the programming context and not necessarily connected to whether the specific choices of coding are ethical.

We did not find examples of programming in education that aims to improve societal problems in our literature review. Max' tasks, however, connect programming with ethical concerns for future children and society and may raise equity issues in the process of solving the task, in line with what Kules (2016, 2018) called for.

Identifying opportunities for uses of drones, and being able to programme for these uses, can facilitate ethical thinking related to drones' more challenging aspects, like how they are used in (illegal) surveillance, warfare, etc. Ethical contexts can be understood as part of what Dufva and Dufva (2016) proposed as code literacy in terms of intentions and the context of the code. In these real-world tasks, the potentially *positive* implications of digital technologies are emphasised. No ethical dilemmas are suggested, but dilemmas associated for intance with misuse of drones or with climate change can be raised during class by the teacher or by students.

These tasks are somewhat different from task 1, as they do not specifically request ethical thinking in line with what is described in topic 3. However, they may facilitate ethical thinking implicitly as the context of the tasks is ethical (doing something good) and they may introduce ethical dilemmas. This implies that the ethical thinking is not primarily on the code level, but connected to the application of the device or to connecting issues. The ethical thinking has thus a weaker link to code literacy, as covered in topic 2. The teacher probably had an ethics-based reason to include these particular themes, which may be related to what we found on topic 1, but the reason is not explicitly expressed in the tasks.

Concluding remarks

Findings from the literature review demonstrate the relevance of ethical thinking in relation to programming. We identified three topics from the literature review: reasons to include ethical thinking in education on programming, code literacy and ethical thinking, and how to facilitate ethical thinking in programming. We used these topics to identify relevant qualities and further potentials of three programming tasks. The three tasks added valuable perspectives that where not documented in the literature review. The review reveals that relevant empirical examples are scarce. Our next step is thus to do empirical research on ethical thinking and programming in the classroom.

References

Balanskat, A., & Engelhardt, K. (2015). *Computing our future: Computer programming and coding – Priorities, school curricula and initiatives across Europe.* European Schoolnet. http://www.eun.org/documents/411753/817341/ Computing+our+future_final_2015.pdf/d3780a64-1081-4488-8549-6033200e3c03

Balanskat, A., Engelhardt , K., Ferrari, A. (2017). The integration of Computational Thinking (CT) across school curricula in Europe. *European Schoolnet Perspective, 2,* 1–4. http://www.eun.org/documents/411753/665824/Perspective2_april2017_onepage_def.pdf/70b9a30e-73aa-4573-bb38-6dd0c2d15995

Bocconi, S., Chioccariello, A., & Earp, J. (2018). *The Nordic approach to introducing computational thinking and programming in compulsory education. Report pre-pared for the Nordic@BETT2018 Steering Group.* https://doi.org/10.17471/54007

Buolamwini, J. (2016, November). How I'm fighting bias in algorithms [Video]. TED. http://www.ted.com/talks/joy_buolamwini_how_i_m_fighting_bias_in_algorithms

Burton, E., Goldsmith, J., Koenig, S., Kuipers, B., Mattei, N., & Walsh, T. (2017). Ethical considerations in artificial intelligence courses. *AI Magazine, 38*(2), 22–34.

Colman, F., Bühlmann, V., O'Donnell, A., & van der Tuin, I. (2018). *Ethics of coding: A report on the algorithmic condition.* European Commission.

Dufva, T., & Dufva, M. (2016). Metaphors of code: Structuring and broadening the discussion on teaching children to code. *Thinking Skills and Creativity, 22*, 97–110. https://doi.org/10.1016/j.tsc.2016.09.004

Estevez, J., Garate, G., & Graña, M. (2019). Gentle introduction to artificial intelligence for high-school students using Scratch. *IEEE Access, 7*, 179027–179036. https://doi.org/10.1109/ACCESS.2019.2956136

Freire, P. (2014). Pedagogy of solidarity: A dialogue. In P. Freire, A. M. A. j. Freire, & W. F. d. Oliveira (Eds.), *Pedagogy of Solidarity* (pp. 35–64). Left Coast Press.

Hursthouse, R., & Pettigrove, G. (2016). Virtue ethics. In E. Zalta (Ed.), *The Stanford encyclopedia of philosophy* (Winter 2018 ed.). Standford University. https://plato.stanford.edu/entries/ethics-virtue/

Kules, B. (2016). Computational thinking is critical thinking: Connecting to university discourse, goals, and learning outcomes. *Proceedings of the Association for Information Science & Technology, 53*(1), 1–6. https://doi.org/10.1002/pra2.2016.14505301092

Kules, B. (2018). Coding with a critical lens: A developing computer programming curriculum for diversity and equity. In P. Wang & A. Green (Eds.), *Proceedings of the Association for Library and Information Science Education Annual Conference* (pp. 31–36). ALISE.

Ladwig, C., & Schwieger, D. (2020). Ethical coding: Privacy, ethics & law in computing. *Information Systems Education Journal, 18*(2), 50–57.

Morris, D., Uppal, G., & Wells, D. (2017). *Teaching computational thinking and coding in primary schools.* Sage.

The National Committee for Research Ethics in Science and Technology (NENT) (2020). *Opinion on research ethics and artificial intelligence.* https://www.forskningsetikk.no/globalassets/dokumenter/4-publikasjoner-som-pdf/opinion-on-research-ethics-and-artificial-intelligence.pdf

O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy.* Crown.

Ravn, O., & Skovsmose, O. (2019). *Connecting humans to equations. A reinterpretation of the philosophy of mathematics.* Springer. https://doi.org/10.1007/978-3-030-01337-0

Rhim, J., Lee, G.-b., & Lee, J.-H. (2020). Human moral reasoning types in autonomous vehicle moral dilemma: A cross-cultural comparison of Korea and Canada. *Computers in Human Behavior, 102*, 39–56. https://doi.org/10.1016/j.chb.2019.08.010

Rodríguez García, J. D., Moreno-León, J., Román-González, M., & Robles, G. (2020). LearningML: A tool to foster computational thinking skills through practical artificial intelligence projects. *Revista de Educación a Distancia, 20*(63). http://dx.doi.org/10.6018/red.410121

Schrier, K. (2015). EPIC: A framework for using video games in ethics education. *Journal of Moral Education, 44*(4), 393–424.

Seoane-Pardo, A. M. (2016). Computational thinking beyond STEM: an introduction to "moral machines" and programming decision making in ethics classroom. In F. J. García-Peñalvo (Ed.), *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 37–44). https://doi.org/10.1145/3012430.3012494

Seoane-Pardo, A. M. (2018). Computational thinking between philosophy and STEM-Programming: Decision making applied to the behavior of "Moral Machines" in ethical values classroom. *IEEE-RITA, 13*(1), 20–29.

Skovsmose, O. (1994). *Towards a philosophy of critical mathematics education.* Springer.

The Ministry of Education and Research [of Norway] (MER) (2020). *Curriculum for the elective subject of programming (PRG01-02).* https://www.udir.no/lk20/prg01-02

The Ministry of Education and Research [of Norway] (MER) (2019). *Curriculum for mathematics year 1.–10. (MAT01-05).* https://www.udir.no/lk20/mat01-05