Navigating Source Code Plagiarism Challenges: Strategies to Mitigate the Impact of COVID-19 Disruptions

Linda du Plessis
https://orcid.org/0000-0003-3697-4782
North-West University
linda.duplessis@nwu.ac.za

Imelda Smit
https://orcid.org/0000-0002-6866-1521
North-West University
imelda.smit@nwu.ac.za

Abstract

In South Africa, the immediate response to the COVID-19 pandemic was a hard lockdown, which shocked the educational community. The disruption to teaching and learning was particularly profound for first-year computing students, especially those with disadvantaged backgrounds. One of the biggest impacts of emergency remote teaching and learning was on assessment, which is widely regarded as the driving force of learning, particularly in the programming context. Source code plagiarism emerged as a prevalent practice during the pandemic due to the challenges students face, including infrastructure limitations, learning in isolation, and the opportunities presented by online continuous assessment practices. Through an empirical study, the authors, as academics, investigated the occurrence of source code plagiarism during the COVID-19 lockdown period, along with the transition required to adjust to a post-COVID setting. The different theories that drive behaviour and decision-making in this context are analysed, and qualitative data is collected using open-ended questionnaires. Findings yield vital recommendations for the mitigation of source code plagiarism. Reflecting on the findings suggests that engaging students on source code plagiarism can assist in establishing shared norms, playing a positive role in reducing source code plagiarism. This is necessary, especially with the recent introduction of artificial intelligence tools such as ChatGPT, which may take source code plagiarism to a new level. Academics face long-term challenges and exciting opportunities in addressing source code plagiarism issues in the post-COVID context of integrating online and face-to-face modalities.

Keywords: Computer programming; source code plagiarism (SCP); source code plagiarism detection (SCPD); theories on behaviour and decision-making

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Introduction

Research conducted by Simatupang et al. (2021) proved that plagiarism drastically increased during COVID-19 and that copy-pasting became a common phenomenon. It restrained the academic environment for nearly two years; no contact classes could be offered, and lecturers used synchronous and asynchronous modes of teaching. The pandemic also caused a significant shift in the way assessments were conducted. Traditional invigilated sit-down examinations have given way to online open-book evaluations without invigilation. Middleton (2020) uses the term "test pollution" to describe the impact COVID-19 had on the assessment of students when it was moved to online platforms. Pokhrel and Chhetri (2021) acknowledged that appropriate measures to check plagiarism are yet to be put in place in many institutions because proctoring software is typically not part of the infrastructure of a contact university, where assessments are assumed to be conducted as sit-down, invigilated sessions (Miller et al. 2011).

This study investigated and reflected on the subject module "Introduction to Computing and Programming" to make sense of the situation, learn from mistakes, and improve the environment in subsequent offerings. Python 3 is the tool used to teach students to code. Python is an interpreted language, and one can run simple Python expressions and statements in an interactive programming environment called the shell (Lambert 2018).

According to Dee and Jacob (2012), limited research findings confirm the effectiveness of frameworks designed to avoid plagiarism. Gregory (2021) is of the view that any attempt to avoid plagiarism without first unpacking its multiple layers will not be effective. The paper intends to provide recommendations for managing source code plagiarism.

Background and Context

Online assessment provided an opportunity for students, particularly those with limited programming experience, to copy source code to pass practical assessments. In a pre-COVID setting, students would do assignments in a practical class where they could obtain guidance from the lecturer and tutors, which limited the need and opportunity to copy source code. Academic misconduct is a persistent problem, and the COVID-19 pandemic, which has imposed constraints on education, has made it challenging to ensure that students work independently. In a study, 93% of lecturers perceive that students cheat more in an online environment when compared to contact learning (Newton 2020). In this study, many students complicated the identification of source code plagiarism without the help of software. As lecturers, it is imperative to navigate this evolving landscape to ensure that students acquire the essential competencies that serve as the foundation for future modules, ultimately enablers to achieve a computing course's desired learning outcomes.

Source code plagiarism (SCP) involves copying or adapting another person's source code and claiming it as your own. This study aims to deepen the understanding of SCP and develop practical solutions to mitigate it. The following questions frame this study:

- How is the occurrence of source code plagiarism perceived by students?
- How can source code plagiarism be mitigated?

The study aims to provide insights into plagiarism behaviour by analysing relevant theories. It then describes research conducted in a first-year programming course at a South African university.

Theoretical Underpinning

A literature review on plagiarism was conducted to establish a theoretical framework for this study. This foundation enables the researchers to present approaches and contextualise the specific approach employed within the context of first-year computing students learning to code. It also places SCP in the context of the broader field of plagiarism, focusing on coding and using Python as a learning tool.

Source Code Plagiarism

According to Parker and Hamblen (1989), SCP occurs when a script is produced from another script with a few routine modifications. These modifications can vary in sophistication and range from simple, often lexical changes to comments, intermediate changes such as formatting amendments, adding declarations, statements, and/or redundant variables, to more advanced changes in program modules, program statements, and decision logic. The significance of this lies in the fact that while lexical changes require minimal programming knowledge, structural changes require a higher level of programming expertise (Maryono et al. 2019; Joy and Luck 1999).

Experienced programmers typically compose intricate scripts to address complex problems and refrain from directly replicating existing code. However, specifications may necessitate purposeful exploration of code snippets from external sources – to solve problems. This practice is categorised as intricate modifications, raising consideration of whether appropriate attribution to the origin of the code is warranted. On the opposite end of this spectrum, novices who replicate source code to resolve elementary problems undermine the fundamental purpose of acquiring coding skills. Recognising that students must commence their learning journey somewhere and using the provided material should be permissible. In such instances, students employing such material are not engaging in plagiarism, a distinction drawn from plagiarism involving the incorporation of materials from domains beyond the scope of supplied material (Joy et al. 2010).

Programming students can be distinguished based on their level of programming skill competency. Sutherland-Smith (2010) asserts that plagiarism is multi-layered, and a spectrum of human intentions can underpin this behaviour, ranging from unintentional to intentional actions (Powell 2012). Other researchers corroborate the multi-layered nature of plagiarism by presenting different views on what constitutes moral behaviour and cheating (Carroll 2002; Ellery 2008; Flint et al. 2006, 145; Gullifer and Tyson 2014). is of the view that there are cases where students are unaware of the nature of plagiarism, resulting in unintentional plagiarism.

Source code plagiarism detection

Plagiarism has been a persistent issue in academic environments, and several tools, such as Turnitin, Grammarly, and Duplichecker, are commonly employed to identify dishonesty in academic writing (Bhosale 2022). However, these tools do not detect SCP. Specialised tools such as Measure of Software Similarity (Moss), Codequiry, and CodeLeaks are required for detecting SCP (Younas 2021). For the current study, Moss was utilised since it is freeware. Whilst literature on plagiarism of text can be used to explain or describe SCP, there are fundamental differences. Computational languages are not spoken languages; hence, arguments based on home language, second language, and so on do not apply (Cosma and Joy 2008).

Ethics scholars expand on the significant factors that motivate actions: the reason for acting, the justification of principles, self-interest, compassion for others, justice, virtues and defining a meaningful life (Ellis 2003; Joy et al. 2010; Gregory 2021). The overarching questions that underpin these theories include the following: how do we define *right* and *wrong* behaviour on an individual, as well as a communal level; what motivates a student to take a specific action, and what can institutions, lecturers and students do to mitigate SCP?

Theories of student behaviour and social contracting are more solution-oriented and view the mitigation of plagiarism as the collective responsibility of the institution, the lecturer, and the student (Breen and Maassen 2005; Macdonald and Carroll 2006). The objective is to extenuate instances of SCP before they escalate into more severe offences. It can be argued that when students perceive a low likelihood of being caught, the threat of external penalties may serve as a deterrent. Therefore, a third category of theories is needed, where a punishment component is present. Care should be taken since traditional theories that solely rely on fear of punishment as a means of prevention are insufficient. Lee (2017) posits a profound theory, contending that wrongful actions can be prevented by appealing to a person's sense of honour and self-respect – implying that SCP can be deterred by providing moral reasons against committing the offence.

Social Learning Theory

Social learning theory (SLT) emphasises the importance of observing and modelling the behaviour, attitude, and emotional reaction of others within a social context (Nabavi

2012). The fundamental concepts that underlie SLT can be categorised into four areas: firstly, individuals can acquire knowledge and skills through observation. Secondly, both intrinsic reinforcement and punishment can influence learning; thirdly, learning may occur without a noticeable behaviour change; and fourth, cognition plays a critical role in learning.

Research findings suggest that in cases where students perceive a lack of repercussions for plagiarism, such behaviour is reinforced (Burnett et al., 2016; Johnson, 2014). However, positive reinforcement, which can simply include not having a negative consequence associated with the action, may encourage both positive and negative behaviours. We concur with Bretag (2013) that educational institutions should nurture the approach to plagiarism as a "*holistic and multi-stakeholder approach*", targeting the development of an academic community based on collective knowledge and observance of ethics and academic integrity.

Integrative Social Contract Theory

Integrative Social Contract Theory applies a contractual approach to decision-making. A social contract comprises three components: the person entering a social contract should be able to exit it as well, and the individual should understand the expectations or norms of the contract and have a voice in setting or changing the contract. These social contracts can be formal or informal agreements and can be constituted on a macro or micro level (Donaldson and Dunfee 1999). A social contract on a macro level typically refers to a shared understanding among community members. Micro contracts refer to more explicit agreements within a community around specific behaviour. According to Gregory (2021), most cases of plagiarism involve a power differential where not every person has the same ability to enter a social contract. This study aims to demonstrate the efficacy of creating a learning environment where students can engage and have a voice.

Problem-oriented theories on behaviour

Various perspectives exist on who bears responsibility for addressing plagiarism. Ethical and criminological theories adopt a problem-oriented approach on one end of the spectrum, holding students solely accountable for their actions. These primary theories are not aligned with the aim of this study and are subsequently not discussed in detail but summarised in Table 1. While these theories may contribute to combatting SCP, their punitive nature is harsher than the approach envisioned in this study, prioritising a solution-oriented focus emerging in subsequent sections.

Table 1: Problem-oriented theories on behaviour

Theory	Focus	Limited relevance to study context
Deontology	An ethical theory that guides and assesses our choices and how we should behave (Freeman et al. 2008, Larry and Moore 2021)	No flexibility: it leaves the person with no chance to consider the circumstances or consequences of an action.
Utilitarianism	Actions are to be judged by their usefulness to produce benefit, advantage, or happiness (Granitz and Loewy 2007).	Utilitarianism does not account for things like feelings and emotions, culture, or justice. "*The greatest good for the greatest number*" is its principle. It creates a black-and-white construct of morality; something is either right or wrong.
Ethical relativism theory	Persons define their own principles and ethical decisions about what is morally good and bad is made by an individual (Eshetu 2017; Pojman 2001).	Ethical relativists endorse the view that moral codes and principles are culture-bound; they deny the existence of overarching and objective moral codes and principles.
Deterrence theory	People are rational actors capable of taking the consequences of their actions into consideration. So, any form of penalty is intended to dissuade potential offenders from plagiarism (Ellis 2003)	Severe punishment or external sanctions will deter perpetrators.
Theory of planned behaviour	The intention of a rational person to act can be accurately predicted from the attitudes towards the action, subjective norms, and perceived behavioural control (Ajzen 1995; Coren 2012, Soomro et al. 2018).	The focus is on understanding the reasoned action of a person in the fields of health, law, marketing, and politics.
Self-interest theory	"One individual must never prefer himself so much even to any other individual, as to hurt or injure that other, to benefit himself, though the benefit to the one is much greater than the hurt or injury to the other." (Smith 1976)	Society will benefit by being free and productive when people act in self-interest, without forcefully interfering with the rights of others.

Research design

An interpretive approach was followed, which recognises that there are multiple experiences and perspectives. Social actors construct their reality through words and narratives (Kozleski 2017). This perspective allows for a more nuanced understanding of a world in which facts and values are intertwined. Interpretivists acknowledge the influence of societal forces on personal experiences and concurrently emphasise the pivotal concept of individual agency, positing that individuals are not mere conduits for

external social influences but active agents capable of shaping and navigating their distinct paths within the broader social context (Mackenzie and Knipe 2006).

Qualitative data analysis was conducted by systematically interpreting student responses to identify codes grouped into categories (Maxwell 2016). The researchers familiarised themselves with the data by reading through it thoroughly. The data was broken down into meaningful units labelled as codes. The next step involved the finding of patterns and connections among the codes. Similar codes were grouped to form broader categories. These categories represent higher-order concepts that encapsulate the coded data. In the discussion of the findings, the authors reflect on the meaning of the derived categories to the research questions and consider the implications and significance of the findings.

Data collection

An open-ended questionnaire aimed to collect information on students' views on SCP and their familiarity with plagiarism, the reasons behind their decision to copy code or not, and what can be done to mitigate SCP was made available online.

Participants

The participants in this study were all first-year university students enrolled on the Introduction to Computing and Programming module. From a cohort of 216 students, 53 students completed the questionnaire. To mitigate self-selection bias, every student had an equal opportunity to participate anonymously (Holtom et al., 2022). Rather than focusing solely on response rates, this research prioritised the data quality collected. During analysis, it was concluded that the qualitative responses proved sufficient richness and depth to contribute to a deeper understanding of SCP (Holtom et al., 2022).

Data Analysis

The analysis of the question "Elaborate on the reason(s) why you copied or did not copy code" allowed for more detailed examples regarding the reasons for SCP, which informed the analysis of the data. The categories, codes, and examples of verbatim student responses are listed in Table 2. The discussion below shows categories in bold, codes in bold and italics, and verbatim responses in "quotes." Students are indicated in brackets (S#).

Table 2: Categories and codes based on verbatim student responses

Category	Response code	Student	Verbatim student responses
Own work	Desire to learn	S3	I did not wish to have a dishonesty case and wanted to learn to solve the problem.
		S19	Copying someone else's work would be playing myself because I would have learned nothing which would backfire soon enough. I want to write my own code as hard as it is. I need the joy of seeing my code run after multiple attempts at what seemed impossible. It makes learning exciting. As a person who knows nothing about coding, I wanna learn as much as possible so I can obtain a valuable skill.
		S21	I did not copy because I want to make my own mistakes and eventually learn where I went wrong and ultimately improving my skills.
	Long term self-interest	S8	I did not code copy because I will not learn anything if I do that, and my peers will not be around during my final exam. Therefore, I did what is best for me and worked alone, coded alone and did not bother anyone. I want to genuinely know how to code, and cheating would mean cheating on myself. I enjoy programming and the more I program, the better I get at it. That's my goal!
	Moral norm	S5	I must do my own work.
		S7	I already know how copy and plagiarism detecting software works, it matches Python scripts by detecting similarities with scripts and again copying one's code would make me an immoral IT specialist and thus block my creativity. I believe if you want to be the greatest in things you are passionate about you must be prepared to go through failure not to fake an achievement I don't deserve. No one promised me that BSc IT would be simple.
SCP Denied	Students sit in the same class	S2	I did not copy code, but my work came out as a dishonesty case. How is it not possible for students taught by the same lecturer to come up with similar codes?
		S29	I didn’t copy a code; I think it was because I used obvious variables like anyone else can use “sum” as a variable that sums up other variables.
Unintentional SCP	Knowledge of SCP lacking	S51	In some cases, I did not copy but I got the answer from the internet, I did not just copy and paste the program, but I did some changes to the program.

Category	Response code	Student	Verbatim student responses
	Work in groups	S24	I did not copy any code rather I shared my code and collaborated with some friends on some assignments.
	Supported by a tutor	S45	One of my scripts was identified as a dishonesty case because I got help from a tutor.
	Peer(s) supported	S10	I did not copy but my code was copied by peers I thought I was helping but I was killing myself.
	How to support a peer?	S9	I helped individuals who would come to me, but I now know how to move around that for the future.
		S12	I thought I was helping a friend by letting him copy my script. I have learned my lesson and swore to never do such a thing again
		S28	I was understanding the work but not in a matter of teaching another peer. I helped someone with reference to how I was answering mine.
Intentional SCP	Fear of failure	S1	I did not understand the work and had difficulty learning the concepts.
	Not understanding the work	S6	I couldn't get enough content for the code due to late registration, meaning I couldn't cover enough study units.
	Poor time management	S25	I asked a friend for an explanation to help understand the work and I did that because I cannot afford to fail this module again.
Student conduct	Academic integrity	S11	Copying code will not help me (or anyone) understand what the code actually does or the concept behind the various functions and structures used.
		S21	I want to make my own mistakes and eventually learn … and ultimately improve my skills
	Confidence in own ability	S7	... copying one's code would make me immoral
		S34	I lacked confidence and the more disappointing my results became the less I wanted to do this module so I avoided it. I am not used to failure and such low results had a huge impact on my emotional health and interest. I just have to work on not being easily discouraged.
	How to provide peer support	S12	I thought I was helping a friend by letting him copy my script ...
		S26	I wrote my own script and shared it with a friend since they are new to programming
	Moral behaviour	S5	I must do my own work

Category	Response code	Student	Verbatim student responses
		S8	... I did what is best for me and worked alone. The more I program, the better I get at it - that's my goal!
	Study skills	S1	I .. had difficulty learning the concepts
	Self-discipline	S52	I did not copy the code. my code was a result of many trials and errors. The problem was not at the side of the lecture, it was me, the student who was too lazy to work
Learning environment	Enrolment support	S6	... late registration, meaning I couldn't cover enough study units
	Infrastructure and resources	S40	For on-campus classes, more engagement is needed. Unlike with Zoom, classes on campus become easier to understand when dependence is not on slides only and lecturers aren't just giving students work to try on their own. Some people can't keep up easily...
	Policy framework	S23	Please give guidelines from the start of the semester on how the dishonesty cases work…
		S34	I did not realize that following a textbook example would count as copying…

Students who chose to do their **work and not** plagiarise were impelled by a ***desire to learn*** and master skills. Some students argued that they are focused on their future careers and, therefore, understand the importance of doing the work themselves: "I did not copy because I want to make my own mistakes and eventually learn where I went wrong and ultimately improve my skills" (S21). Linking with this notion is ***long-term self-interest***, as one student lamented, "I want to genuinely know how to code" (S8). In support, students (S5, S7) argued that engaging in SCP is against their norms.

A small group of students (S2, S29) **denied** their involvement in **SCP** even though Moss identified it as similar to a peer's work. In such cases, the simplicity of a problem or detailed instructions may lead to sscript similarities. This response confirms the finding of Ngo (2016) that plagiarism may be reduced through assessment design.

When it comes to student engagement in **unintentional SCP**, it is evident that ***knowledge of SCP is lacking*** among students; "I got the answer from the internet" (S51). Some students ***work in groups*** – "I shared my code and collaborated with some friends on some assignments" (S24); others were ***supported by a tutor*** (S45) or were ***peer supported***; "my code was copied by peers. I thought I was helping, but I was killing myself" (S10). This problem is exacerbated by the easier and quicker way to share one's code with a peer instead of guiding a peer in developing code. A student's perspective

on ***supporting a peer*** is succinctly captured in the following statement: "I thought I was helping a friend by letting him copy my script. I have learned my lesson and swore to never do such a thing again" (S12).

Fear of failure, reflected in "I cannot afford to fail this module again" (S25), ***not understanding the work*** – "I had difficulty learning the concepts" (S1), and ***poor time management*** resulting in *"(not) cover(ing) enough study units*" (S6) were the drivers of **intentional SCP**.

The data analysis revealed several development areas regarding student conduct, such as ***academic integrity*** (S11, S21), ***confidence in own ability*** (S7, S34), *how to provide* ***peer support*** (S12, S26), ***moral behaviour (***S5, S8), ***study skills*** (S1), and ***self-discipline*** (S52). The responses touched on the learning environment, including enrolment support to prevent "late registration" (S6), **infrastructure and resources** to enable constructive "engagement" (S40), and a **policy framework** to provide "guidelines" (S23).

Analysis of the question: "How can the risk of SCP be mitigated?*"* elicited responses that could be clustered under three categories, as summarised in Table 3.

Table 3: Lecturer responsibility towards mitigating SCP - category and codes

Category	Response code	Student	Shortened verbatim student responses
Lecturer responsibility	Assessment design	S12	Provide us with lots of Python problems, give more ghostbuster tests …
		S14	The lecture could supply more programming tasks …
		S16	Supplying us with more programming problems
	Course design	S7	Offer extra information about the wonders of what technology can do to show students why technology will forever be a valuable source of the economy.
	Create opportunities for conversation	S13	With having to understand the causes that lead to dishonesty case ...I understood the risks ... I then found it easier and not that challenging to communicate with the lecturer and ask questions …
		S27	I feel like the lecturer should be open for face-to-face consultation because some of these things aren't very understandable, they need some severely deep understanding that an email just won't do.
	Make class recordings	S49	By recording our online class so that we can have something to refer to when we are lost
	Regular feedback	S2	The lecturer should analyse each assignment after submission and not wait for the end of the semester to identify dishonesty cases
	Teaching and learning strategy	S25	The lecturer can at least record the lessons so that we can be able to go through it multiple times until we understand, since we do not have any contact classes.
		S3	By providing ... more detailed examples … learn to approach the problem differently.
		S8	She provided more than enough weekly assignments and had supplemental instruction classes that helped.
		S9	Our lecturer could offer additional classes ...

The codes indicate that the lecturer should focus on ***assessment design*** – "more ghostbuster tests" (S12), ***course design*** – *"*offer extra information about the wonders of what technology can do" (S7), ***creating opportunities for conversation*** – **"**the lecturer should be open for face-to-face consultation" (S27), ***making class recordings*** – **"**recording our online class" (S49), ***providing regular feedback*** - "*... not wait for the end of the semester to identify dishonesty cases*" (S2), and adjusting the ***teaching and learning strategy*** – "by providing ... more detailed examples … to approach the problem differently" (S3). These perspectives serve as valuable guidance for shaping a new normal in the post-COVID era.

Findings from Data Analysis

The analysis revealed that the learning environment hosted by the institution emerged along with the lecturer's input and the students' responsibility as co-owners of teaching and learning.

The importance of a social contract, supported by ***awareness of SCP*** and knowledge of SCP, which is ***lacking*** to create a shared understanding of what constitutes plagiarism, is central to the outcome of this study. A holistic approach to learning should underpin the process of countering plagiarism. The co-responsibilities of the three significant entities are shown in Figure 1 and informed by the derived codes.

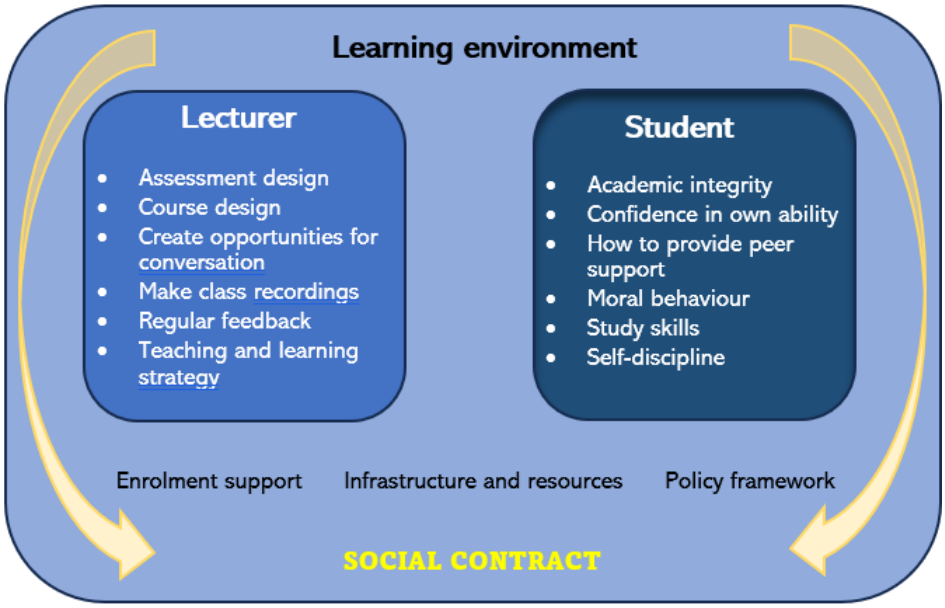

Figure 1: Learning environment-lecturer-student obligations in the SCP context

Mitigating plagiarism is a continuous process that should encompass the learning environment, the lecturer and the student, who enters into a social contract upon enrolment for a module. Students should be empowered to improve their time management and enable effective teamwork and strategies to cope with the demands of the course and future job requirements. The focus on learning as a stepping stone to a career should be emphasised. The focus should not only be on plagiarism and consequences but also on factors for completing a course. This proposition aligns with the graduate attributes of the institution (NWU 2021). Students should show a:

> "Willingness to take responsibility for the consequences of their judgements, decisions and actions based on a strong value system, and an awareness and understanding of moral, ethical, social, cultural and environmental issues".

Recommendation

The academic institution should create an environment and provide support structures that enable lecturers to manage academic integrity effectively. The policy framework should be updated regularly to allow the lived experiences of academics and students to improve the regulatory environment. In addition, the availability of automation software tools for SCPD, providing feedback-as-guidance and assessment-as-feedback, will save lecturers time on these activities, especially in large classes (Helminen and Malmi 2010). It should be noted that these tools may reduce but would not fully replace the need for human intervention and may be costly (Säfsten Winroth and Stahre 2007).

Conclusion

The value of a social contract and giving a 'voice' to staff and students is paramount. This study confirms that engagement in SCP may influence behaviour. Further research should assess how reciprocal engagements impact ethical relativism on SCP. The approach includes policies and training but extends beyond these to include dialogue. Preparing students for the world of work includes instilling in them work ethics and the importance of social contracting. Building on social learning theory, students should focus on the long-term benefit of quality education. Robust engagements about SCP are essential in educating students about plagiarism and fostering longer-term ambitions to master programming competencies instead of just passing assessments. Our findings affirm the co-responsibility of various role-players in the institution, such as policymakers, academic developers, technology support staff, lecturers, and students, to improve academic integrity. The solution to combating SCP is not to return to a pre-COVID scenario only but to involve students in crafting the future approach towards learning to code. With the advent of artificial intelligence tools such as ChatGPT, the computing academic fraternity is facing long-term challenges and exciting opportunities to address source code plagiarism issues.

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