Characteristics of a CS Graduate Student

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Computing Science (CS) is seen as a tool of absolute and pure logic, an incarnation of efficiency, analytics, and control [4]. Thus, political and public debates often frame CS as a solution to a multitude of societal (e.g. neutral judging [8]) and environmental (e.g. optimising electricity usage [5]) problems [18]. Indeed, CS possesses potential for doing good. However, one must also acknowledge that CS has been the cause of problems, environmental (e.g. electronic waste disposal [20]) as well as societal (e.g. amplify racism, sexism, ableism, and other forms of discrimination [**?**]). Recent history has shown how damaging CS can be when misused (e.g. Cambridge Analytica [2]) or when unexpected or undesired (side) effects (e.g. mental health epidemic [28]) materialise. Despite the power of CS for both good and ill however, CS graduates are often unaware of the power they hold over persons, societies, and the environment.

The entanglement of CS, environment, and culture is indisputable, yet, socio-ecological responsibilities are undiscussed in university science and engineering education; despite the fact that CS falls into the realm of Dual Use Research of Concern (DURC). According to the World Health Organisation, DURC describes "research that is intended to provide a clear benefit, but which could easily be misapplied to do harm" [**?**]. The extent of DURC education in CS today is based on the strongly held — yet false — belief that things like codes of conduct can fully avoid, or keep within bounds, the negative consequences arising from abuse and unintended side effects. In other spheres of STEM, such as biology, nuclear technology, chemistry, dual use questions are discussed and addressed in the education and the technological development process. However, in CS, this problem is not as prominent nor as discussed. Confusingly, dual use is sometimes applied very differently in CS: it may simply mean the usage of an item or software in two different ways or contexts [22].

A stark majority of CS engineers and researchers, namely 71%, are not familiar with the concepts of DURC [**? ?**]. A truly terrifying number considering that in 2016, NATO has agreed that cyberspace is a military domain [**?**] and many countries have since invested in offensive and defensive IT capabilities [24]. Internationally and on a global scale it seems, the harmful potential of CS and its DURC outputs is recognised: social media is (mis)used in political conflicts (e.g. US elections 2018 [2]) [24], face recognition is (mis)used in stifling protests (e.g. Hong Kong Protests 2019 [**?**]), and mobile phone technologies are (mis)used in governmental tracking [**?**]. It seems, every aspect of CS can be weaponised, regardless of whether this was the intention of the engineers or researchers.

University science and engineering education often does not include discussion of the responsibilities of CS, or such discussion is present as a small fraction of the curriculum. However, it is important that the concepts such as reflexivity,

ethics, responsibility, justice, equity, equality, and sustainability in computer science be included as mandatory content in (under)graduate computer science education. As Gilda Barabino [3] put it:

> In addition to engineering fundamentals and technical skills, students need values and attitudes to [...] responsibly apply engineering for the good of society.

It is indisputable that CS graduates and higher education institutions teaching CS have socio-ecological responsibilities. CS impacts societies, cultures, and the environment. As in other areas of STEM, the field of CS should assume responsibility over those it influences. As a first step in this direction teachers and graduates of CS, as well as their institutions, must resume this responsibility – to educate the public, avoid the misuse of CS for unethical purposes, be mindful of unexpected long-term effects, and train students to consider ethical aspects in decision-making processes.

This essay argues that:

> Computing Science education must be *critical* in nature, to help form not only good engineers, but also good citizens.

Therefore, the most desirable characteristics of a CS graduate are reflexivity, ethicality, and accountability. An understanding of one's own positionality, one's own values, one's own responsibility. To put it succinctly, of one's impact on society, culture, and the environment is mandatory in education of computing scientists.

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