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The use of people's online digital traces has given rise to concerns for democracy. The digital traces may affect the individual's life in unexpected and negative ways. Such traces may also be of importance for understanding the spread of disinformation and the like. This paper reports on a Foucault inspired discourse analysis of the Swedish upper secondary mathematics curriculum. Two discourses are construed in the intersection of critical thinking, democracy, and this new technology. Skovsmose's concept of mathemacy is used to identify what is critical knowledge and what is not. The first construed discourse is, "With knowledge in formal mathematics, critical thinking on democracy will follow." The second is, "Rather a personal career than a critical citizenship." Neither of the discourses promotes a need for mathematics education to change due to new technology with regards to critical thinking.

Keywords: Critical mathematics education, digital traces, democracy, discourse, curriculum.

Introduction

We leave digital traces of our actions online. They are used in algorithms that update the feed in social media and provide us with search engine results. This enhances experiences and makes them more personalized. However, most users do not know the exact mechanisms behind what is seen on the screen. In conjunction with research across various fields, this gives rise to concerns about citizens' ability to critically assess mechanics of democratic elections, economic exploitation of vulnerable social groups, and the flow of (mis)information, etc. Our interest in this paper is in how this critical gaze is highlighted in school and in governing school documents, especially in mathematics education.

This paper reports on a discourse analysis of the current Swedish mathematics curriculum for upper secondary school, adopted in July 2021. The analysis is inspired by the viewpoint that teaching mathematics is a political activity due to its contingency and sociological impact (Gutiérrez, 2013; Valero & Orlander, 2018). Since society is in a state of constant change, there is always a need to assess whether the curriculum is in tune with contemporary societal challenges. The analysis takes a particular interest in potential issues for democracy related to the new technology of collecting and mining people's digital traces. By democracy, we mean a way of living together in a society with a shared belief in values such as equality and equity, and where different opinions can meet in debate without any hampering interference from misinformation. One incentive for writing this paper is to contribute to an exploration of how critical thinking for democracy can be nurtured within mathematics education, as in e.g., critical mathematics education (Skovsmose, 2005). The specific aim of the paper is to investigate curriculum aspects of the current situation of critical thinking in relation to democracy and this new technology. This could inform future explorations of what can be improved (C. H. Andersson, 2021). The research question is: what discourses can be construed in the intersection of critical thinking in relation to democracy and the changing role of mathematics in society due to the new digital technology?

Digital traces and democracy

The following examples are intended to illuminate some topics that we view as possible to draw on in a version of mathematics education which includes a focus on critical thinking in relation to digital traces and democracy.

Digital trace data is processed in algorithms to extract information that was never explicitly there. This fuels the new technologies of machine learning and artificial intelligence that are increasingly becoming a driving force in the economy (Villani et al., 2018). Data can be, and is, used to prey on vulnerable social groups with targeted advertising (O'Neal, 2016). If the workings of the new economy are opaque to most citizens, democracy has few regulatory controls to alleviate such ramifications. With knowledge of how targeted advertising works, citizens could also start to think critically about it in new ways. When machines learn from human behaviour, there is a risk that undesirable attributes flaws such as racism and sexism may be embedded in the algorithms and lead to discrimination (Villani et. al., 2018). If this happens to the algorithms that steer and select information online, these algorithms could become a structure that reproduces social injustice. The risk is exacerbated if the algorithms are believed to be neutral.

Social media can be used to change voting behavior (Bond et. al., 2010), which has been attempted on a large scale to support a particular candidate through the use of digital traces (Sabbagh, 2020). This means that the digital trace you leave can act as someone else's tool without your knowledge, and furthermore be used against your interests. It is debatable to what extent this is successful, nevertheless the strategic use of digital traces has become an integral part of election campaigning. Attempts to swing public opinion can also operate through personal digital traces since they cluster people into groups with similar interests. Such groups are used as levers in disinformation campaigns where group members' views are cultivated and directed (Starbird et al., 2019), demonstrating another way for the digital traces to act as tools for others.

Digital traces are relevant to take into consideration when understanding search engines. One example is how these attributes more relevance to clicked links (Shah, 2021). When sensational (mis)information is uploaded, the resulting clicks out of users' curiosity increase its visibility in new searches, which then result in even more clicks, and a relevance feedback loop that changes further search results. The interaction between human behavior and the algorithms can propel the visibility of the sensational, rather than the relevant. This knowledge may be the basis of a new perspective and critical thinking in relation to news found with search engines, for example.

Previous research in mathematics education

Critical Mathematics Education (CME) has a long history through the work of Freire, Frankenstein, Skovsmose, and others, of engagement in how mathematics education could support democracy (e.g., Skovsmose, 2005). There is research addressing topics around new technology and democracy, for instance how people meet new technology albeit being unaware of how mathematics operates in it (e.g., Straehler-Pohl, 2017), the need for mathematics education to address computer science (e.g., Borovik, 2017), and students' ethical reasoning when data science is discussed in mathematics education (Register et al., 2021). However, we have been unable to locate any research with a specific interest in mathematics in relation to critical thinking on the ramifications for democracy of digital traces, the specific interest of this paper.

Democratic values aimed at in governmental documents in Sweden

Democracy occupies a salient position in the Swedish Education act (Sveriges Riksdag, 2021), stipulating that education shall convey and anchor the "fundamental democratic values "on which Swedish society rests" (4 §, chapter 1, our translation). It is not specified, however, if this means merely conveying democratic values as such, for example how education is organized, or whether students furthermore should attain *specific knowledge* that supports the sustainability of democracy, such as through developing argumentative speech skills. Other steering documents and government agencies have the option to add such levels of detail. Concerning search engines, Sundin (2015) showed that the Swedish primary and lower secondary school curriculum treated them as neutral, and thereby hindered critical media literacy. More recently though, the Agency of Education has in different ways started to express the need for compulsory school pupils to be informed on how the algorithms of search engines work (C. Andersson, 2021). The mathematics curriculum subject to analysis in this paper is thus enacted in a time of increasing awareness of the importance of online algorithms, and is a part of a collection of documents that have the overarching of aim of conveying and anchoring democratic values.

Theory

This paper takes a dynamic view of theory, meaning that theory adapts to the questions asked. The paper coordinates (Prediger et al., 2008) Foucault's (e.g., 1995) framework with CME (e.g., Skovsmose, 2005). Coordination is achieved through using Foucault's framework for how knowledge, practice, and the dynamics of structure and agency are intertwined within institutions; while CME is used to pinpoint the characteristics of mathematical knowledge from mathematics education that, if the discourse allows, could benefit the development of critical thinking. Coordination of the two frameworks takes place only within the frames of this paper's research question.

Foucault's (2002) framework defines discourse as language use, norms, habits, artifacts, institutional praxis, etc. A discourse is a collection of such matters together with the discourse's rules of formation that act as gatekeeper for the creation of objects (including abstract) that can be a part of the discourse. There is also an enunciative function of statements which is the action performed by them (Foucault, 2002). Through the limits of what is said and acted, including what cannot be said within the discourse, discourses portray structure-agency dynamics and how knowledge and power are produced and linked. This can be related to agency in educational institutions or within an educational system (Boistrup, 2017).

The second theoretical framework has a CME perspective, since we draw on Skovsmose (2005) to introduce *mathemacy* as a competence that is a "reference to mathematics, in the broad sense of the term, but also reference to a notion like democracy interpreted as a way of living … [and] a capacity to modulate, and to see a situation as open to change" (pp. 187). Critical thinking is similarly defined in this paper as the *competence to think beyond the most common practice of the local milieu, realize the contingency of situations and evaluate alternatives*. The similarity enables us to use characteristics of mathemacy for critical thinking. Skovsmose (2005) addresses three distinct types of knowledge related to mathematics, rephrased by us as (1) mathematics knowing itself; i.e., dealing with mathematics notions (2) pragmatic knowledge; i.e., applying mathematics notions in different situations, and (3) critically reflecting on such applications including the consequences of different mathematical decisions in people's lives. The third knowledge type, reflective knowledge, is an important characteristic for the development of mathemacy, whereas the other two are not always required. This has affected the analysis, which is described below.

Methodology and Process

Data

The 27-page national mathematics curriculum for upper secondary school in Sweden begins with a preamble followed by the general aim of the subject. Then follow 11 course titles, each of which is described by two sections: *central content* to be taught and the *knowledge requirements* for each grade (The National Agency for Education, 2021). The 11th, and last, course's central content does not stipulate any specific content but just give examples of possible content, and is excluded from our analysis. The ten remaining courses are divided into three parallel tracks, vocational education, social sciences and art, and science and technology. Many words and phrases in the central content are repeated across courses, or in the descriptions of grades within or between courses. The document is in Swedish. Quotes in this paper are translated to English by the authors.

Method of analysis

The analytic procedure was a back-and-forth process between three steps, though, for clarity, they are described as three steps following each other. The first step was to formulate codes. Codes were allowed to be intersectional to encompass interplay between concepts. The code *individual* was used throughout the analysis corresponding to when students were mentioned separately and in subgroups. Two codes were related to the first two knowledge types identified by Skovsmose (2005), i.e., (1) mathematical knowing itself and (2) applying mathematics. The code *to-do* encompasses limited and specific tasks within the realms of either of the knowledge types (1) or (2). The code *to-know* concerns mathematical knowing, either in (1) mathematics itself, or (2) in relation to applications of mathematics. Two codes were needed to pinpoint Skovsmose's third knowledge type, critical reflections of mathematical applications (called reflexive knowing). One of these codes is *to-judge*, which concerns all instances where there is a judgment of mathematical methods or other mathematical acts. The other code needed for fulfilling the reflexive knowing is *society*, which concerns instances where mathematics is connected to the wider context beyond school.

The second step was to use the analysis program Nvivo. Using the program's tool *cases*, the document was divided into overlapping sections: preamble, aim of the subject, central content, knowledge requirements, and the different educational tracks. Every piece of coding was thereby labeled with at least one case referring to its locality in the document. The outcome was analyzed by both quantification and interpretation. An example of the former is statistics on the simultaneous appearance of codes. An example of the latter is investigating whether codes tend to appear close to each other, e.g. in the same sections of the text. Another example of the latter is reinterpretation of statistics due to the repetitive nature of the text.

The third step was discourse analysis inspired by Foucault. This analysis was based on the first two steps of analysis, which gave information about patterns of what is written and what is not. This informed us about what the rules of formation of objects for a construed discourse could be. At this stage there were many alternatives for such rules and, consequently, for possible construed discourses. To reduce this complexity, we followed Foucault's (2002) suggestion to start with what appear to be tensions in relation to our research question. Discourses are broad and general in the sense that both sides in a conflict within an institution or a discipline can use them, or they can remain invariant across other kinds of tensions. Consistency was achieved by identifying an enunciative function for the statements, so that what first appeared to be a tension or contradiction was dissolved in light of how the rules of the particular discourse work. Each such consistent view on the research question, based on rules of formation of objects and specified enunciate functions for statements, became a construed discourse named with a phrase capturing its central theme.

Main findings and construed discourses

The construed discourses in this paper are (1) *with knowledge in formal mathematics, critical thinking on democracy will follow*, (2) *rather a personal career than a critical citizenship*, and (3) *society as an aim but not to be assessed.* Since the third discourse differs from the others with its focus on assessment, it is outside the scope of this paper and will not be described in the findings.

The first discourse, *with knowledge in formal mathematics, critical thinking on democracy will follow*, has formal mathematics as a vehicle to have mathematics education updated to the new digital technology and any related issues with democracy. The curriculum's preamble posits, "as society is digitized, mathematics is used in increasingly complex situations" (The National Agency for Education, 2021, pp. 1). However, the document never explicitly follows up on what this change means for mathematics education, nor does the curriculum make any statements that can be construed as being about critical thinking. One of the codes for critical thinking is *to-judge*, and it has a textual separation from the other codes. For instance, it has few simultaneous appearances with other codes, and it is separated by punctuation from other codes in a way that is not typical of the rest of the text. A similar textual separation of codes exists for the code *society*. This does not only mean that *to-judge* and *society* are separated from other codes, but it also means that they are separated from each other. Hence, the text does not connect the markers whose simultaneous appearance could have indicated critical thinking on a societal level. There is only one instance of a simultaneous appearance of *to-judge* and *society*: "[f]urthermore, the teaching must contribute to the students developing knowledge about the significance and use of mathematics in other subjects as well as in a professional, social and historical context" (The National Agency for Education, 2021, pp. 1). The coding of *to-judge* is too weak here for critical thinking, and derives only from the word "significance" (Sw. betydelse) as a value-laden word. Instead of explicitly describing critical thinking, or how the new digital technology is affecting mathematics education, the curriculum describes mathematics education in other ways. It is described as something that the students shall be able *to-do* (307 occurrences) and *to-know* (145), and to a lesser degree *to-judge* (57). When "judging" occurs, it is typically found in students assessing the plausibility of their answers in problem solving, which further emphasizes *to-do* as the most prominent since it concerns the outcome of students doing. The closest the text ever comes to students questioning, not only answers but also methods, is in the central content: "[e]valuation of properties and limitations of mathematical models" (pp. 3). However, there is no discussion of alternative models or any arguments for choosing between them. Overall, the text mainly describes mathematics education as something that concerns separate individuals and their ability to perform tasks. This can be seen as situated within Skovsmose's description of mathematical and pragmatic knowledge, with little reflective knowledge. This is underpinned by the analysis of the tandem appearance of codes, which clearly shows a strong link between *to-do* and *individual*. The occurrence of this pair is most common in the knowledge requirements. The absence of any explicit statements on critical thinking in relation to democracy, and the absence of anything on new technology after its mention in the preamble, have the same root in this discourse. They are interpreted as redundant by the in lieu salient position of performing mathematical tasks. In this discourse, it is sufficient for students to know formal mathematics. This knowledge will provide them with a sufficient toolbox, and since formal mathematics does not change, no further pointers on how to use it in the context of democracy or new uses of digital traces in society are needed. The rules of formation do not allow the creation of the object *student's mathematically guided critical thinking on democracy*, because that object is subsumed into the object *student's knowing mathematics*. The discourse does not in any way dispute the need for mathematics education to engage in critical thinking or democracy; on the contrary, the enunciative function for statements on mathematical tasks is to show how to do this. Formal mathematics resolves the issue!

The second discourse, *rather a personal career than a critical citizenship*, is orientated around tensions within the text. One tension from the viewpoint that steering documents may concretize overall aims, is that the code *society* first has a clear presence in the preamble, is reduced in the aim of the subject, only mentioned sparsely in the central content, and is non-existent in the knowledge requirements. Navigating through the steering documents from the overarching aim in the educational act down to individual students' learning goals seems to leave a trace of diminishing pronounced societal aims. The only other topic in the text that goes beyond the classroom setting is in mathematics for professional life. In contrast to the societal aim, however, the notion of mathematics to support a career is still clearly present in the central content. There is even a separate subsection only for this in the courses for vocational education; for other tracks there is specific content included that resonates with their education track, such as geometric sums (useable for calculations on loans) for economically oriented study-programs, and vectors (for physics) for science and technology. In relation to our research interest, this discourse *does not* promote the need for mathematics education to engage in critical thinking related to democracy, including in relation to any new technology such as use of digital traces. When the text mentions society these functions as lip service to the overarching aim in the education act. The enunciative function in this discourse for society thereby creating a hindrance to any actual engagement with it.

The two discourses described above can both be connected to previous research. The discourse, *with knowledge in formal mathematics, critical thinking on democracy will follow,* has similarities with Valero and Orlander's (2018) description of an implicit assumption in mathematics education of the intrinsic power of mathematics that automatically gives students access to powerful and universal reasoning. They describe it as an often dominant view in curricula formulation, and note that a tension has been identified in research between this view and views that center more on uses and applications of mathematics. The discourse, *rather a personal career than a critical citizenship,* resonates with Jablonka's (2003) description of mathematical literacy for developing human capital, which emphasizes economic growth for both the student and society.

Discourse analysis is an interpretive process that can take different routes. The analysis in this paper provides merely one way of viewing the mathematics curriculum. In this case, the construed discourses challenge the notion of a curriculum that is regularly updated due to new uses of mathematics in society. Taking the (self)regulation induced by discourses into account, a change towards a more vivid ambition to nurture critical thinking for the benefit of democracy in a rapidly changing society would therefore be held back by the inertia of these discourses. Therefore, it would be interesting to investigate if teachers and students also engage in these or similar discourses when reflecting on digital traces, and critical mathematics education, vis-à-vis democracy. In that case, it might be possible to identify if, and how, they engage in other discourses which may alleviate some of the official resistance to change.

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