Algorithms in Education: Underlying Mindsets

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Abstract

Mindsets play a (hidden) role in algorithm design. Mindsets make algorithms a human affair: algorithms are shaped through often implicit and hidden underlying mindsets of designers, and these mindsets result in algorithms that are highly influenced by a specific (human) perspective. As algorithms are becoming increasingly relevant to society, science and technology, and even canonized in for example "dataism", it is imperative that explicit attention should be paid to these underlying mindsets in general and in university education in particular [1] [2]. In our presentation we present a model (DOLM) to design courses and programs to critically reflect on underlying mindsets of algorithms and on the (development of the) perspectives of students. We aim at supporting university lectures and program directors to develop educational activities in which this type of reflection takes central stage - in their own teachings, curricula and research. We thus expect to contribute to (i) the development of the awareness of students regarding the existence of underlying mindsets in science and applications of science, (ii) their growing ability to critically reflect on these mindsets, and (iii) to the role and development of their own perspectives in (i) and (ii). We also aim at enlarging their capacity to defend their choices concerning algorithms in a responsible way and, as a more general goal, to help them to deal with complex and controversial problems in their role as students and as future scientists and academic professionals [3].

Keywords: *Algorithms, underlying mindsets, critical reflection, student's perspectives*.

1. Introduction

The problems associated with the development of algorithms and their use, in particular the role of different kinds of mindsets (existing of (often hidden) underlying biases and ethical values) are widely recognized. In general, the notion that algorithms are value-laden is gaining support [4]. Cathy O'Neil for example, points out that the mathematical models powering the data economy are based (most of the time) on well-argued and intentionally sound choices of fallible human beings: "many of these models encoded human prejudice, misunderstanding, and bias into the software systems that increasingly managed our lives." The title of her book, *Weapons of Math Destruction*, speaks volumes [5]. When people take algorithms for granted and think that they provide 'objective' outcomes, they can create and amplify filter bubbles and echo chambers in the recipients. People then see what they want to see [6]. Whatever conclusion is arrived at, a critical attitude toward algorithms seems necessary.

As algorithms are becoming increasingly relevant to society, science and technology, and even canonized in for example "dataism", it is imperative that explicit attention should be paid to these underlying mindsets in general and in university education in particular.

Examples of educational programs that focus on (i) the development of intellectual skills for analyzing algorithms or (ii) the integration of ethical reasoning into research and scientific practices related to algorithm design are manifold: from learning to recognize fake news [7] to trying to integrate ethics into a computer science curriculum [8]. Paying explicit attention to the influence of underlying mindsets is, however, quite rare, though not completely absent. The same holds for articles focusing on the development and transformation of these underlying mindsets. To get a firm grip on the learning process in which systematic attention is paid to the fruitful development of mindsets, however, more is needed.

In this article we present a model (DOLM) to design courses and programs to critically reflect on underlying mindsets of algorithms. The DOLM and its principles and goals have been extensively discussed elsewhere [3] [9]. We will limit ourselves to illustrating the model by presenting an example related to algorithms and their underlying mindsets.
Section 1 discusses the theoretical principles, structure and objectives of the DOLM. Section 2 elaborates on the DOLM with a case about the dismissal of a teacher, who is highly valued by parents and school management, but is nevertheless dismissed based on the results of an algorithm-driven quality test.

2. The Dilemma Oriented Learning Model (DOLM); Theoretical Principles, Structure and Objectives

2.1 Theoretical Principles

In the DOLM, dilemmas are related to conflicts between elements of underlying mindsets and can be part of the complex controversial issues described as ill-structured problems by King and Kitchener: “They cannot be described with a high degree of completeness or solved with a high degree of certainty” [10]. The DOLM starts with this type of problems. Mezirow's Transformative Learning Theory is considered an educational tool for the 21st century “to educate youth and adults to become competent, interdependent, inclusive, and responsible people who are both intellectually and emotionally mature and committed to lifelong self-learning…” [11]. This theory can be seen as the theoretical basis for the structure of the DOLM. In this theory, ‘learning’ is seen as a process by which students use their existing experiences and interpretations of the world around them to arrive at adapted or new interpretations that can drive future action. This view can be related to the mental legacy of influential authors such as Dewey [12], Habermas [13], [14], Freire [15], Kuhn [16], Kolb [17], 18], and Inhelder & Piaget [19] and can be summarized as follows: [20], [21]: *Students’* new *experiences enable them to create transformations in their perspectives through self-reflection on their paradigms or mindsets.* Transformative learning transforms problematic mindsets, making “them more inclusive, discriminating, open, reflective, and emotionally able to change” [22]. Recently, interest in Mezirow’s theory has been growing in several disciplines in the field of university education [23], [11], [2].

2.2 Structure

The DOLM confronts the student with the same problem and the same dilemma in four phases (A: the intuitive phase; B: the scientific phase; C: the philosophical phase; and D: the review phase). The intuitive phase concerns the dialogue between the student and his or her fellow students about their choices and argumentation. Their initial perspectives and resulting positions are up for debate. In the scientific phase, the focus is on scientific information on the one hand and the dialogue between students, fellow students, scholars, and scientists on the other. Here, different ways of thinking from a multitude of perspectives are discussed. In the philosophical phase, philosophers intervene with their focus on (i) underlying frameworks in scientific theories in general and mindsets in algorithms in particular and (ii) student’s thinking patterns and perspectives in particular. In the review phase, students look back on the whole process and reflect on their choices and the reasons for those choices.
Each phase starts with a process called ‘clarifying’, raising (new) questions about the definition of the problem and the dilemma and looking for relevant information that can be processed according to the phase in question. Next, arguments are presented and ordered (‘weighing’) and, based on these arguments, choices are made and further substantiated (‘making choices’). Explicit questions regarding the choice are raised about elements of the underlying perspectives and mindsets such as assumptions and values. Students discuss their arguments, choices, and reflections about the underlying perspectives and mindsets with their fellow students (‘communicating’) and write a report about their final findings during each phase. Based on these reports, they make a final report in phase D. In this review phase, the students reflect on their transformation process and the extent to which the objectives of the model – open mindedness and the ability to reflect – have been achieved.

2.3 Objectives of the DOLM: Open-Mindedness and the Ability to Reflect

Open mindedness means that students can recognize and critically analyze their own possible filter bubbles and echo chambers as well as those of others [6]. They learn to approach the pros and cons of choices in a systematic way with equal attention to all positions and equal respect for the input of those who think differently. Regarding their judgment process, they also learn to include more aspects of the complex problem they are faced with. They show improvement at bringing together the perspectives behind the intuitive, scientific, philosophical, and final reflections, paying special attention to the personal aspects of the complex problem under scrutiny.

The ability to reflect means that – during the process of making and justifying choices – students accept the uncertainties associated with conducting scientific research, developing technologies and social and personal well-being. They recognize that mindsets and perspectives can play a leading and decisive role in this process. Their knowledge claims are viewed from the point of view of (i) consistency, (ii) coherence with the available information, and (iii) the ability to evaluate this information critically. They are open to new data and new perspectives and are willing to revise their conclusions and knowledge claims based on these data and perspectives. In this process, dialogue with other students and lecturers is central.

In the pre- and post-test design of the DOLM, it is possible to monitor modifications students undergo during the process. When students completely change their own mindset, *accommodation* will occur. *Assimilation* takes place when students supplement or partially adjust their mindset. Students enrich their arguments and perspectives without modifying their original choice. In that case, their views are substantially refined and deepened. It also happens that students, without using any substantive arguments, *stick* to their own position. In that case, students do not learn from the process and the information offered.

3. Elaboration of the DOLM

3.1 The Disorienting Dilemma

To increase students' abilities regarding open-mindedness and the ability to reflect, DOLM-based education starts with a complex controversial problem. This problem includes a (disorienting) dilemma that demands the students to make choices. Throughout the DOLM teaching/learning process, the choices to be made increase in terms of diversity, complexity, and ability to reflect. To introduce a complex controversial problem, methods like videos, podcasts, and written assignments can be used. In this section, we discuss an example of complex controversial problems in which algorithms and underlying mindsets are involved: the story of Sarah in connection with educational studies. Discussing this example will help to further introduce the DOLM.

3.1.1 The Case of Sarah: Sarah's Story

In her book Cathy O'Neil [5] tells the story of poorly performing schools and the dismissal, in and around 2010, of hundreds of teachers in Washington DC. This dismissal was based on scores on an algorithm-based assessment tool for teachers (IMPACT). For Sarah Wysocki, a fifth-grade teacher, her low score and the subsequent dismissal came as a bolt out of the blue. The principal of her school had praised her, and the parents were also very happy and satisfied with her. One evaluation praised her attention to the children, and another characterized her as "one of the best teachers I have ever met." Despite these positive evaluations, she scored too low on the algorithm-based assessment tool to be allowed to stay at her school as a teacher. Given this information, DOLM-related educational activities can be initiated by formulating the dilemma as: "Is Sarah's dismissal justified or unjustified?"

3.2 The Phases of the DOLM and Sarah's Story

3.2.1 Phase A (Intuitive Phase): Student's Initial Perspectives

This phase, also called the pre-test phase, starts with studying the case and dilemma.
Students make a choice in phase A based on their reflections from their own, already existing perspective. Phase A is essential. Here, students make explicit the ideas they already have: their point of view with regard to the problem, their professional knowledge, their ideas about (good) scientific research, methods, and algorithms used. Their perspectives function as starting points in their learning process. In the following stages, these perspectives are critically examined and developed towards a more deliberative perspective (characterized by open-mindedness and the ability to reflect).

3.2.1.1 Sarah's Story

In this case, the dilemma was formulated as follows: Is Sarah's dismissal justified (see test results) or unjustified (see positive views of school leaders and parents) and why? In this phase, the main question is how students evaluate Sarah's dismissal by themselves without further information. Possible views can be presented and discussed in the classroom as follows:

1 The decision is accepted because it was based on an algorithm; it is thus objective and reliable;
2 The decision is accepted because the learning outcomes of students determine the quality of the teacher;
3 The decision is not accepted because it is felt that the opinion of parents and school management is more important; the results obtained by the algorithm are questioned;
4 The decision is not accepted because it is thought that the school management can better support Sarah in teaching practices than fire her.

If one offers a DOLM course on this dilemma, a majority of undergraduate students can be expected to opt for Sarah's dismissal. Based on King and Kitchener's research into the development of students' ability to reflect [24], they are expected to respond from a pre-reflective and narrow-minded mindset. That means they think science should be authoritative and objective. Algorithms, tests, and their results belong to science and should therefore not be questioned. From this perspective, the so-called subjective opinions of school leaders and parents cannot compete with science.

3.2.2 Phase B (Scientific Phase): Scientific Perspectives

In this phase, the case and dilemma from phase A continues to play a role. But now different experts in the discipline throw light on the choices and arguments. These experts may reasonably disagree, depending partly on their different perspectives (related to underlying mindsets of the algorithms under scrutiny). Students have the opportunity to study the expert's views and weigh their arguments from their own points of view. This phase helps students understand, assess, and include different scientific theories in their arguments and choices.

3.2.2.1 Sarah's Story

The first expert supports Sarah's dismissal. The students in the schools in Washington performed poorly. That is why some action had to be taken. This first expert agreed on the plan to develop 'objective' algorithms, independent of peer and parents' opinions, to test students for their learning progress and to determine which teachers were performing well and which teachers were underperforming. The latter should then be dismissed. The IMPACT assessment tool for achievement scores in math and reading was correctly developed and managed. Teachers whose students scored poorly were dismissed and other teachers appointed in their place. From this perspective the underlying mindset of the algorithms is not problematic and algorithms are seen as objectivity. It was considered positive that an algorithm was used here because the 'objectivity' of algorithms was considered self-evident and indisputable. Compared to "the subjective opinions" of school leaders and parents, an objective test was seen as a big advantage (O'Neil 2016: 1-20). Questions about the validity and reliability of algorithms – related to biases, interests and hidden values (phase C) – were not raised by this expert because of his supposedly unquestioned belief in their objectivity.

According to O'Neil's account, the second expert believed Sarah was wrongly dismissed, pointing to reliability and validity problems. In Sarah's case, the reliability problem is that the outcome of IMPACT is based on the learning outcomes of only 25-30 students [5]. The question is whether the population is large and varied enough to be able to draw conclusions about Sarah's qualities as a teacher. Should a procedure not involve at least a thousand students and many more groups of students? And should the results not also be compared with those of other teachers?

Regarding the validity problem, Sarah's dismissal seems, at first glance, to be justified because it is assumed that the students' performance on the test is an indication of Sarah's (poor) teaching ability. A range of variables plays a role in the determination of this ability, from socio-economic factors to individual learning problems. The ability of the teacher is one of these variables. In order to gain insight into the teacher's ability, it is necessary to determine the role of the teacher within this complex whole. Without pre- and post-tests, IMPACT remains a black box with regard to the teacher's role in the educational process.

Another problem regarding validity concerns the fact that there is no accurate picture of the students' learning performance at the start of Sarah's lessons (there are no valid pre-test data). Insight into the progress of learning depends on, among other things, reliable data concerning the initial situation of the student. If, for instance, teachers' assessments in this initial situation turn out to be too high and if knowledge of this fact has been ignored in the test, then the results regarding the students' progress are not valid. In that case, Sarah cannot be held fully responsible for her students' scores as the test does not measure what needed to be measured, i.e., the quality of the learning progress and, in this context, the quality of Sarah's performance. According to O-Neil [5], research does indeed show that student achievement was overvalued by teachers at the schools Sarah's students come from. Therefore, these results should not be the starting point for determining the quality of Sarah's teaching. Because of these problems (reliability and validity), her dismissal does not, according to the second expert, seem to be justified.

3.2.3 Phase C (Philosophical Phase): Philosophical Perspectives

In phase C, students have the opportunity to study from a philosophical perspective (i) their own perspectives, and (ii) the mindsets underlying algorithms that were clarified in phases A and B. Regarding the story that is central in our article, this philosophical analysis focuses on positions in philosophy of (social) science, philosophical anthropology, and ethics. It reflects critically and explicitly on the underlying perspectives and mindsets that emerged in phases A and B, and, more specifically, on the assumptions and presuppositions of these perspectives and mindsets. Typical for this phase are questions regarding the consistency, coherence, and plausibility of the assumptions and presuppositions under scrutiny. Applied to the subject of this article, philosophical reflection regarding mindsets of algorithms might refer to the criteria that determine the creation of certain data (and not alternative data), the identification and genesis of the categories that are applied in data analysis and in the construction of algorithms, and the arguments and concepts that appear in articles based on Big Data research in which algorithms play a decisive role. These criteria are implicitly involved in the underlying mindsets related to the design of algorithms under scrutiny.

3.2.3.1 Sarah's Story

Sarah received very positive evaluations from the school principal and the parents of her students regarding her teaching and attention toward her students. Due to low scores on an algorithm-based assessment tool for teachers (measuring among others the effectiveness of teaching math and language skills), however, she was dismissed. For those responsible for her dismissal, the 'objective facts' based on the data from the algorithms outweighed the positive assessments of the principal and parents. Experts discussed interesting reliability and validity problems with respect to this decision (phase B).

In Sarah's story we are faced with questions about the possibility of objectivity in algorithm design. Insight into the way underlying mindsets operate causes serious criticisms about claims to objectivity. Claims concerning the objectivity of algorithms are usually based on the same belief that is at stake in the conception of science as value-free. Analyses from the field of the philosophy of science show that this conception is flawed. Just as is the case with algorithm design, values and other elements of underlying mindsets play a decisive role in the practice of science, as many examples and theoretical deliberations demonstrate [9].

Regarding the discussion about reliability and validity, one could raise a more fundamental question: What is the right level of analysis in this type of problem? Should one focus on the individual level and discuss the 'accomplishments' of individual teachers such as Sarah? Or should attention be paid primarily to the collective level on which, for instance, the educational system of a country operates? With respect to teaching, it is immediately clear that both levels are relevant: (i) the characteristics and abilities of individual teachers with their beliefs, choices, and actions and (ii) the way the educational system is organized, facilitated, and embedded in a society with its own cultures, laws, and administration. An interesting question is whether these two levels are really about different phenomena since every society is composed of individuals. This question becomes a philosophical question when one asks if the social level can be reduced to the individual level. Here the teacher can introduce several related problems such as the one about multiple realizability and that of the remainder, and a number of different positions related to ideas about supervenience and downward causation [25]. These questions about reduction can be related to Sarah's story – for instance, whether learning results are dependent on different variables and can thus can be achieved in multiple ways. We then operate on the level of (i) underlying mindsets regarding algorithms and (ii) the way these results are used in the question of Sarah's dismiddal.

In Sarah's story, a causal relation sometimes seems to be assumed between individual education or an educational system on the one hand and what is learned on the other. But does 'good' education *cause* positive learning effects? Or do we need to speak about 'correlations' and 'reasons' instead of 'causal relations'? Regarding the social sciences, this discussion is related to a more general question: Can human action be causally explained? This discussion is too broad and too specialized to deal with here [25], but it might be interesting for students to discuss at least the difference between causes, correlations, and reasons, and to apply this difference to Sarah's story.

Another problem with Sarah's dismissal has to do with the ethical choices made in her story. Among the many factors that play a role, ethical choices can be important in the process of designing algorithms as well [26]. In Sarah's story, we see that the underlying idea – that a school can perform better if the failing teachers are dismissed and replaced by other teachers – is not discussed or contested. An alternative could be that a school's performance can be improved if the poorly performing teachers receive support. These questions are of course related to ideas about the best way to improve the quality of education as well as how people are dealt with within an organization. And here ethics comes in. To make students think about the different options, it could be interesting to introduce several ethical theories such as virtue ethics, deontology, and consequentialism. Students can also be made aware of the fact that ethical debates differ from discussions about, for instance, the soundness of mathematical evidence.

3.2.4 Phase D (Reflection Phase): Personal Perspectives

In this phase – the post-test phase regarding the DOLM – the student reflects on the developments, processes, and results of phases A-C. The student is asked to compare the results, indicate possible progress, or, conversely, obstacles standing in the way of the objectives of open mindedness and the ability to reflect and relate them to the methods and content used. The teacher and the researcher can accomplish this task, based on the choices and arguments of the students in the three phases, or in a more quantitative way, as in, for example, pre- and post-tests, in which those objectives are operationalized on the basis of measurable student behavior. The Reflective Judgment Model of King and Kitchener can be helpful in describing learning results [10]. In this phase students thus mainly reflect on the development of their own perspectives, a development that was – during the whole learning process – taken into consideration in relation to their analyses and discussion of the underlying mindsets of algorithms.

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