# Mapping Upper Secondary Computer Science Specifications Against UNESCO's Framework of AI Learning Outcomes

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**Abstract**

In this paper, we explore the coverage of artificial intelligence (AI) and machine learning in upper secondary computing specifications, guided by an AI curriculum mapping framework established by UNESCO. This framework organizes learning outcomes into three main AI categories: a) Knowledge, b) Skills, and c) Values & Attitudes; and is based on AI curricula developed and implemented by 11 governmental or otherwise authorized bodies. Although the UNESCO framework is fairly comprehensive, Ireland or nearest neighbours, were not included in it. Through the lens of the UNESCO framework, we investigate how the upper secondary computing curriculum specifications of Ireland and six other regions with English-based, similar educational systems (England, Malta, Northern Ireland, Scotland, Wales, and Western Australia) align with the 222 AI learning outcomes identified by UNESCO. This allows us to map the existing educational terrain, identifying both the common threads and divergences in how AI is taught at the upper secondary level, without suggesting any normative judgments on these curricular efforts. Our intention is to help other regions align their curricular efforts best. By doing so, we aim to contribute to a broader understanding of how AI education is currently structured across different contexts, offering insights into the multifaceted dimensions of preparing students for the complexities of AI technology and its implications. This study shows that AI education pays little attention to the technical aspects of algorithms, big data principles, environmental considerations, and ethical considerations. This underscores the need for a more comprehensive approach that includes practical and ethical dimensions of AI technologies.

**Keywords**

Artificial Intelligence, curriculum mapping, England,, Ireland, K-12, Malta, Northern Ireland, Scotland, school, second-level, secondary, specification, UNESCO, UK, Wales, Western Australia.



## 1. Introduction

In 2022 UNESCO released the *"K-12 AI Curricula: A Mapping of Government-Endorsed AI Curricula,"* [1] report focusing on the development and implementation of AI education in primary and secondary schools worldwide. The UNESCO study examines AI curricula approved, or in the approval process, by national or local governments. Two surveys, asking about AI curricula in K-12 education, were distributed: one to representatives of 193 UNESCO Member States and another to over 10,000 stakeholders in the private and third-level sectors. The research also included semi-structured interviews with UNESCO Member State representatives, non-profit leaders, developers, academics, and industry professionals. A significant effort was made to map out the learning outcomes (LOs) outlined in each curriculum, with a review of related textbooks and other materials.

The research revealed that 11 states (Armenia, Austria, Belgium, China, India, Republic of Korea, Kuwait, Portugal, Qatar, Serbia, and United Arab Emirates) have developed, endorsed, and implemented 14 AI curricula, and that 5 more states (Serbia, Germany, Jordan, the Republic of Bulgaria, and Saudi Arabia) have AI curricula under development and likely to receive governmental endorsement. The research also included 2 non-governmental curricula that featured AI LOs and were being implemented in cooperation with local governments (the Applied Design, Skills, and Technologies curriculum - the Yukon Territory in Canada; and the MIT DAILy curriculum - the United States); related works like the

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'IBM-CBSE AI Curriculum' for grades XI & XII, Microsoft's textbook series in India, and the Microsoft Computer Science Curriculum Toolkit; and curricula from IBM, Microsoft, Intel and MIT that were used as benchmarks.

The LOs of the curricula studied in the UNESCO report were extracted through an analysis of the frameworks and programs of study, and the curricula were analyzed comparatively in aggregate to map out LO specifications across grade levels. The types of engagements that were listed as curriculum objectives at each level were also extracted. It is important to note that the report makes no claim on what should or should not be included or covered in a K–12 AI curriculum, but merely represents current practices. We have numbered the 222 LOs found in the UNESCO AI framework (p.39-44) [1] for clarity, and they are listed in Table 2 to 11.

## 2. AIM & RELATED WORK

The Computer Science curriculum for Ireland [2] was not included in the UNESCO study. Nor were the curricula of its nearest (in terms of geography and educational system) English speaking neighbours (England [3, 4], Scotland [5, 6], Wales [7], Northern Ireland [8], Malta [9, 10], and Western Australia [11, 12]). In this paper we address this omission by systematically mapping the upper secondary Computer Science (CS) curriculum specifications from these 7 regions against the UNESCO [1] framework for the categorization of AI LOs - see Tables 2 to 11. We are not aware of any other publications that have utilized the UNESCO AI Curricula Mapping Framework. It is, however, mentioned in several papers [13, 14]. This mapping exercise is intended to identify key themes, strengths, and potential gaps in current AI educational practices, thereby offering insights into how these specifications can be further developed or enhanced. The aim of this paper is to answer the following research question:

**How do the learning outcomes of the upper secondary CS specifications from Ireland and its nearest English speaking neighbours align with the UNESCO mapping of learning outcomes in the AI categories: (a) Knowledge, (b) Skills and (c) Values & Attitudes?**

## 3. METHOD

This section describes the curriculum mapping process adopted in this work and describes the different grade levels of the regions studied, and how they align with each other.

### 3.1. Curriculum Mapping

A curriculum map is a visual depiction of the elements and features of a curriculum that makes the individual components visible for easy examination and possible comparison [15]. This research involves employing curriculum mapping as a methodological tool to conduct a comparative analysis of upper secondary CS specifications from 7 regions. The primary focus of this comparison is to understand the extent to which these specifications have integrated AI into their educational frameworks. A systematic approach was adopted for data extraction and input - findings were input into a standardized instrument which facilitates easy analysis and comparison of the AI components across different regions. This analysis presented a challenge. Some LOs, while not explicitly stated, are intricately woven into the content of some curricula. On the other hand, there are instances where some LOs fall short of comprehensive realization within the specification given in some curricula.

This complexity underscores the need for a discerning approach when evaluating the alignment between educational objectives and content, ensuring a deeper understanding of the extent to which LOs are integrated and fulfilled. Thus, we used the following scale to quantify whether a particular LO appears within a curriculum specification: (1) Not addressed, (2) Partially addressed, (3) Interwoven into content, and (4) Addressed in content. The LOs were initially rated by one author. A second author then reviewed their rating, and discrepancies were discussed and reconciled through discussion, including the third author.

| EQF | AGE | | IRELAND | [WALES] & ENG & (N IRL) | SCOTLAND | | MALTA | | WEST AUS |
|---|---|---|---|---|---|---|---|---|---|
| Level 4 | 17-18 | SECONDARY | 6th year<br>Leaving Certificate<br>NFQ IE Level 5 | Year 13 (14)<br>A-level<br>[CQFW] or RQF Level 3 | 6th year - S6<br>Advanced Higher<br>SCQF Level 7 | HIGHER | Form 6 - Upper<br>Adv. Matriculation (AM)<br>MQF Level 4 | SENIOR | Year 12<br>WACE ATAR<br>AQF - no level |
| (Level 4 - 5 Scotland) | 16-17 | | 5th year | Year 12 (13)<br>AS Level<br>[CQFW] or RQF Level 3 | 5th year- S5<br>Higher<br>SCQF Level 6 | | Form 6 - Lower<br>Intermed. Matric. (IM) | | Year 11 |
| Level 1 - 3 | 15-16 | | 4th year<br>(optional) | Year 11 (12)<br>GCSE<br>[CQFW] or RQF Level 1 | 4th year - S4 | SECONDARY | Form 5 - Year 11<br>Secondary Education Cert. | SECONDARY | Year 10 |
| | 14-15 | | 3rd year<br>Junior Cycle<br>NFQ IE Level 3 | Year 10 (11) | 3rd year - S3 | | Form 4 - Year 10 | | Year 9 |
| | 13-14 | | 2nd year | Year 9 (10) | 2nd year - S2 | | Form 3 - Year 9 | | Year 8 |
| | 12-13 | | 1st year | Year 8 (9) | 1st year - S1 | MID | Form 2 - Year 8 | | Year 7 |
| | 11-12 | | 6th Class | Year 7 (8) | Primary 7 | | Form 1 - Year 7 | | Year 6 |

**Table 1**
The correspondence of ages, grade levels, and exams between secondary school students in Ireland, the UK (England, Wales, Scotland, Northern Ireland), Malta, and Western Australia. Levels are aligned with the European Qualifications Framework (EQF), the National Framework of Qualifications for Ireland (NFQ IE), the Regulated Qualifications Framework for England and Northern Ireland (RQF), the Credit and Qualifications Framework for Wales (CQFW), the Scottish Credit and Qualifications Framework (SCQF), the Malta Qualifications Framework (MQF), and the Australian Qualifications Framework (AQF).

## 3.2. Grade Levels

The European Qualifications Framework (EQF) [16, 17], established in 2008, serves as a common reference framework for qualifications (EQF Levels 1-8). Table 1 shows qualifications approved by national qualifications frameworks of the United Kingdom (England, Scotland, Wales and Northern Ireland), Ireland, Malta and Western Australia mapped against Level 1 to 4 of the EQF. The specifications chosen for analysis are positioned at Level 4 on the EQF (except Scotland - Level 4/5). The UNESCO report mapped the 222 AI LOs against three grade levels: primary, middle and high school (high school being grades 10-12 for most countries) [1]. Our focus is on what students are being taught in CS in the final 2 years of school (ages 16-18 years). The grade levels and curricula studied for Ireland and the 6 other regions investigated in this paper are described below.

**ENGLAND** The General Certificate of Secondary Education (GCSE) is an academic qualification that is taken in a range of subjects in England, Wales and Northern Ireland (Year 11, Level 2 EQF). It is followed by the Advanced Subsidiary (AS) and Advanced (A-level) exams, typically studied during the final two years of second-level schooling. The General Certificate of Education Advanced Level (GCE A-levels) is an entry qualification for universities, normally based on three A-level grades. The CS subject is optional to students who may choose this from a large selection of other subjects. A number of examining boards offer different A-Level CS curricula (for example, AQA [18] and Cambridge [19]), all of which must comply with UK government regulations set by the Office of Qualifications and Examinations Regulation (Ofqual). OCR (Oxford, Cambridge, and RSA) [20] is one of the leading UK awarding organizations (they offer over 100 occupational qualifications in addition to the GCSEs and A-levels in more than 40 subjects) and we use their curricula in our study. At the A-Level, our reference was *OCR, Computer Science, H446, Version 2.7, March 2024* [4], and at AS Level, *OCR, Computer Science, H046, Version 1.5, February 2024* [3].

**WALES** The Welsh Joint Exam Committee (WJEC) [21], was established in 1948[1] and offers over 400 internationally recognized GCSE, AS, A-level and vocational qualifications. The regulator, Qualifications Wales, decides on the subject content and the assessment rules for GCSEs, AS and A-levels. The AS and A-level CS qualifications, were introduced for first teaching from September 2015, and are available to all schools and colleges in Wales. In June 2023, 659 students sat the A-level CS

[1]In Welsh, WJEC is known as Cyd-bwyllgor Addysg Cymru (CBAC), and it also operates under the Eduqas brand.

exam, with 31.6% of students achieving an A* or A grade. At A-Level and at AS Level we consulted the *WJEC CBAC, GCE AS/A Level in Computer Science, Version 2, March 2019* specification document [7].

**NORTHERN IRELAND** The Council for the Curriculum, Examinations & Assessment (CCEA) [22] was established in 1994, and is funded by and responsible to the Department of Education. GCE A-levels are offered at Level 3 on the Regulated Qualifications Framework (RQF). The AS and A-Level GCE courses in Digital Technology were first taught from September 2016. In the Summer of 2023, 596 students completed the subject at A-Level, with 34.2% achieving an A* or A grade. Students in Northern Ireland may also take examinations set by other UK boards such as OCR or AQA. For A-Level and AS Level, our guidance came from *CCEA GCE Specification in Digital Technology, updated September 2019* [8].

**SCOTLAND** Unlike some other jurisdictions where schools can select from a range of examination bodies to present their students, the Scottish Qualifications Authority (SQA) [23] is the only body in Scotland[2]. Scottish Higher exams are a one year course, and students can use a second year of study to complete Advanced Highers. In the University of Edinburgh [25], for example, Advanced Highers are not required for entry (with the exception of medicine and veterinary medicine), but it is strongly recommended that students pursue their studies at a more advanced level by taking at least one subject at Advanced Higher. We consulted *SQA, Advanced Higher Computing Science, C816 77, Version 3.1, September 2023* [6] at A-Level, and *SQA, Higher Computing Science, C816 76, Version 3.0, May 2023* [5] at AS Level.

**IRELAND** The State Examinations Commission [26] is responsible for the development, assessment, accreditation and certification of the second-level examinations of the Irish state: the Junior Cycle and the Leaving Certificate. The Junior Cycle concludes with a state assessment, formerly known as the Junior Certificate (JC), at Level 3 on the National Framework of Qualifications for Ireland (NFQ IE). The Senior Cycle ends with the Leaving Certificate (LC) exam, the results of which are used for university admission (Level 5 NFQ IE, Level 4 EQF). Exams are offered at Ordinary and Higher level, and students typically complete 6 LC subjects at the end of their sixth year of secondary education. In 2018, the LC CS subject was rolled out in a pilot phase to 40 schools around Ireland [27]. In 2024, 2,470 students sat the Leaving Certificate Computer Science examination at Higher level with 16.3% achieving a H1 grade [26]. The *Computer Science, Leaving Certificate, Ordinary and Higher Level, updated 2023* specification document [2] was our reference.

**MALTA** In Malta the Matriculation and Secondary Education Certificate (MATSEC) Examinations Board offers examinations at two levels: Secondary Education Certificate (SEC) examinations and Matriculation examinations. The latter are offered at Intermediate Matriculation (IM) and Advanced Matriculation (AM) levels. The IM level Computing is intended as a natural progression from SEC level and covers a portion of the AM level syllabus. An 18-year-old student in Malta typically sits for the Matriculation exams - this is at Level 4 on both the Malta Qualifications Framework (MQF) and the EQF. For AM Level, we referred to *MATSEC Advanced Matriculation AM Syllabus 2025, Computing, AM 07* [9], and for IM Level purposes, we referred to *MATSEC Intermediate Matriculation IM Syllabus 2025, Computing, IM 07* [10]. 148 students registered to sit for AM Computing in 2023 [28, 29, 30, 31].

**WESTERN AUSTRALIA** Senior secondary schooling in Western Australia covers students in Year 11 and Year 12, in which students typically complete the Western Australian Certificate of Education (WACE). Australian Tertiary Admission Rank (ATAR) courses and their exams contribute to the WACE, and are administered by the School Curriculum and Standards Authority (SCSA) [32]. In this study we referred to the *SCSA Computer Science ATAR course* [33] (a List B course [34]) which is organized into a Year 11 syllabus [33] and a Year 12 syllabus [35], both effective from January 2024.

[2]The Scottish Government has recently announced that SQA is to be replaced by a new qualifications body in 2025, which will also take on SQA's current accreditation and regulation functions [24].

| VALUES & ATTITUDES OUTCOME MAPPING Section 1 -Personal | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Interest in ICT** | E | S | W | N | M | A | I | **5 Critical thinking and reflection** |
| | X | X | | X | X | | 1.1 Explores existing AI tools | | | | | | | | 5.1 Designs, develops and employs strategies for solving real-life problems using computational thinking |
| | | | | | | | 1.2 Creates innovative solutions through AI tools | | | | | | | | |
| | | | | | | | **2 Persistence/resilience** | | | | | | | | 5.2 Explains how the programmers' bias influences the fairness of AI rules |
| | | | | | | | 2.1 Solves problems using programming methodology | | | | | | | | |
| | | | | | | | 2.2 Tests and redesigns artefacts and products | | | | | | | | 5.3 Compares, analyses and critically evaluates information and digital content (e.g. to recognize manipulation) |
| | | | | | | | **3 Personal empowerment** | | | | | | | | |
| | | | | | | | 3.1 Creates a project using design thinking | | | | | | | | **6 Entrepreneurship** |
| | | | | | | | 3.2 Researches exposed private data on the internet | | | | | | | | 6.1 Uses design thinking methodology to produce a prototype |
| | | | | | | | **4 Reflection** | | | | | | | | |
| | | | | | | | 4.1 Reflects on how 'my personal future work' may be impacted by AI | | | | | | | | 6.2 Develops awareness of entrepreneurship principles/processes to implement innovative ideas |
| | | | | | | | 4.2 Describes the role and importance of AI and its applications | | | | | | | | |
| | | | | | | | 4.3 Explores emerging technologies that have the potential to disrupt the way people live, learn and work | | | | | | | | |

**Table 2**
Based upon Section 1 of the 'Values & Attitudes Outcome Mapping' (p. 44) table in the UNESCO [1] AI curricula mapping framework. An X indicates a learning outcome is absent (neither expressly nor implicitly included) from upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

| VALUES & ATTITUDES OUTCOME MAPPING Section 2 - Social | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Collaboration/Teamwork** | E | S | W | N | M | A | I | **2 Communication** |
| | | | | | | | 1.1 Works as part of a team or group | | | | | | | | 2.1 Creates a story and illustrations using GANs |
| X | | X | X | X | | | 1.2 Implements a project as part of a team | | X | X | X | X | X | X | 2.2 Writes guidance for AI developers to ensure that AI is made ethically |
| | | | | | | | 1.3 Collaborates online as a member of a team | | | | | | | | |

**Table 3**
Based upon Section 2 of the 'Values & Attitudes Outcome Mapping' (p. 44) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

## 4. Results

In Tables 2 to 11 we have identified those LOs that are not addressed (neither expressly nor implicitly included) in the specification documents, and they are symbolised by an X. While there are other LOs that are not thoroughly covered in the curricula, we aim to highlight those AI LOs that we found to be entirely overlooked. We discuss these findings under the three AI categories from the UNESCO framework: Knowledge, Skills, and Values & Attitudes.

**Values and Attitudes:** Across all regions, there is a common trend of under representation of values and attitudes related to AI in curricula (Table 2 to 5), particularly in the "Social" and "Societal" sections (see Table 3 and 4). This suggests that there is a broader need for educational systems to incorporate these LOs to ensure students not only develop technical skills but also cultivate a responsible and ethical mindset towards AI. For example, without addressing topics such as the environmental cost of AI or its potential to reinforce socioeconomic inequalities, students may lack the critical perspective needed to innovate responsibly or advocate for equitable policies.

| VALUES & ATTITUDES OUTCOME MAPPING Section 3 - Societal | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Respect for others** | E | S | W | N | M | A | I | **3 Integrity** |
| | | | | | | | 1.1 Engages respectfully with others | | | | | | | | 3.1 Understands methods of mitigating/lessening bias in AI algorithms |
| | | | | | | | 1.2 Protects personal data and own/others' privacy | | | | | | | | |
| | | | | | | | **2 Personal responsibility** | X | X | X | X | X | X | | 3.2 Designs an end-to-end ML process that maximizes transparency and ensures fairness |
| | X | X | X | X | X | | 2.1 Disposes of technology properly | | | | | | | | |
| | | | | | | | 2.2 Understands that humans control AI and ML | | | | | | | | **4 Tolerance** |
| | | | | | | | | | X | | X | X | | | 4.1 Shows tolerance for different ideas/positions |

**Table 4**
Based upon Section 3 of the 'Values & Attitudes Outcome Mapping' (p. 44) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A), Ireland (I).

| VALUES & ATTITUDES OUTCOME MAPPING Section 4 - Human | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Respect for the environment/sustainable mindset** | E | S | W | N | M | A | I | **2 Commitment to equity** |
| | | | | | | | 1.1 Understands the environmental impact of technology | | | | | | | | 2.1 Reflects on access to AI |
| | | | X | X | | | 1.2 Recognizes the interactions between nature, technology and society | | X | | X | X | | | 2.2 Understands how computational and environmental costs lead to inequity in developing AI |
| | | | | | | | 1.3 Understands how computational and environmental costs can be reduced | | | | | | | | |

**Table 5**
Based upon Section 4 of the 'Values & Attitudes Outcome Mapping' (p. 44) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A), Ireland (I).

**Skills:** Table 6 highlights the exclusion of AI skills, such as creating predictive models and programmatically controlling robots. Without exposure to these skills, students may struggle to grasp the practical applications of AI. In Table 7, large gaps persist consistently across all regions. Key topics such as chatbots, deep fakes, classifiers, and regression algorithms are underrepresented. This reflects a narrow focus within existing curricula which prioritizes general or high-level knowledge over hands-on, applied skills necessary for understanding and developing AI. This gap not only limits students' ability to engage with real-world AI applications but also hinders their ability to critically analyze and respond to the implications of these technologies. Table 8 highlights significant gaps in addressing the ethical and societal impacts of AI across the curricula in the seven regions analyzed. These omissions include critical topics such as algorithmic bias, fairness, accountability, and transparency — issues that are increasingly pivotal as AI systems become more embedded in decision-making processes across sectors.

| SKILLS OUTCOME MAPPING Section 1 - AI Foundations | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Algorithms** | E | S | W | N | M | A | I | **Data Literacy** |
| | | | | | | | 1.1 Recognizes patterns | | | | | | | | 4.1 Saves, changes, and sorts simple databases |
| | | | | | | | 1.2 Follows clear instructions for action (algorithms) and carries them out | | X | X | | | X | | 4.2 Creates visualizations of numerical and textual data |
| | | | | | | | 1.3 Formulates clear instructions for action (algorithms) verbally and in writing | | X | | | | | | 4.3 Searches for, selects, and collects data from a range of sources using appropriate search strategies |
| | | | | | | | 1.4 Creates an algorithm and the relevant flow chart iteratively | | | | | | | | 4.4 Organizes collected information (e.g., by using data labels and categorizing) |
| X | X | X | X | X | X | X | 1.5 Creates a predictive model | X | X | X | X | X | X | X | 4.5 Manipulates data, makes calculations, and creates simple charts with a spreadsheet |
| | | | X | | | | 1.6 Implements complex data structures and fundamental algorithms (e.g., for sorting and searching) | | | | | | | | 4.6 Uses ICT tools to manage and maintain a relational database |
| | | | | | | | | | | | | | | | 4.7 Works with relational databases to produce reports |
| | X | | X | X | | | 1.7 Evaluates the efficiency of an algorithm in terms of time and space | | | | | | | | 4.8 Evaluates the quality, authenticity, and accuracy of data |
| | | | | | | | 1.8 Optimizes computational procedures (to require fewer steps) | | X | | | | | | 4.9 Applies criteria to assess the credibility and reliability of data sources |
| **2 Programming** | | | | | | | | X | X | | | | X | | 4.10 Implements automated data collection processes and manages data storage on a wide range of physical media and cloud platforms |
| X | X | X | X | X | X | | 2.1 Programmatically controls a robot | | | | | | | | |
| X | X | X | X | X | X | X | 2.2 Constructs simple code scripts using block-based programming | X | X | X | X | X | X | X | 4.11 Parses IoT data streams and creates alerts for anomalous conditions such as extreme winds |
| X | X | X | X | X | X | X | 2.3 Creates a mobile application with a block-based programming language | X | X | X | X | X | X | X | 4.12 Transforms unstructured data into structured data |
| | | | | | | | 2.4 Converts algorithms to code using a text-based programming tool | | | | | | | | 4.13 Uses software tools or platforms to organize, calculate, present, and safeguard data |
| | | | | | | | 2.5 Codes in one or more programming languages | | | | | | | | 4.14 Creates SQL scripts to manage normalized databases |
| | | | | | | | 2.6 Masters basic programming structures (e.g. branches, loops, procedures) | | | | | | | | 4.15 Uses ICT tools to transform data into information to support accurate decision-making |
| | | | | | | | 2.7 Assesses user interfaces (usability, intuitiveness) and the technical processes behind them | | X | | | | | | 4.16 Uses a range of models and charting methods to analyze, predict, and communicate data stories |
| X | X | X | X | X | X | X | 2.8 Uses, creates and reflects on coding (e.g. cipher, QR code) | | | | | | | | |
| | X | | | | | | 2.9 Creates code to manipulate local data files | | | | | | | | |
| X | X | X | X | X | X | | 2.10 Creates software to control a robot or another computing device | | | | | | | | |
| | | | | | | | 2.11 Uses modular programming methods in a variety of programming languages | | | | | | | | |
| | | | | | | X | 2.12 Develops an application using object-oriented programming | | | | | | | | |
| | | | | | | | 2.13 Develops secure and user-friendly programs taking into consideration accessibility requirements | | | | | | | | |
| **3 Contextual problem-solving** | | | | | | | | | | | | | | | |
| | | | | | | | 3.1 Creates simple programs or web applications with suitable tools to solve a specific problem or perform a specific task | | | | | | | | |
| | | | | | | | 3.2 Designs, develops, and employs strategies for solving real-life problems through decomposition and pattern identification | | | | | | | | |
| | | | | | | | 3.3 Evaluates possible technological solutions and selects a suitable one also taking into account proprietary and free software | | | | | | | | |

**Table 6**

Based upon Section 1 of the 'Skills Outcome Mapping' (p. 42 - 43) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

| SKILLS OUTCOME MAPPING Section 2 - Understanding, Using and Developing AI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 AI techniques** | E | S | W | N | M | A | I | **2 AI technologies** |
| | | | X | | | | 1.1 Classifies objects by characteristics | X | X | X | X | X | X | X | 2.1 Builds and tests a classifier using a teachable machine or similar AI tool |
| X | X | X | X | X | X | X | 1.2 Constructs a decision tree (paper prototype) | | | | | | | | |
| X | X | X | X | X | X | X | 1.3 Designs a workflow to train and test an AI algorithm | X | X | X | X | X | X | X | 2.2 Builds a chatbot with support |
| | | | | | | | | X | X | X | X | X | X | | 2.3 Constructs and controls a simple robot that can use AI |
| X | X | X | X | X | X | X | 1.4 Cleans and prepares textual data for analysis and ML | X | X | X | X | X | X | X | 2.4 Programs an autonomous robot |
| X | X | X | X | X | X | X | 1.5 Designs and tests supervised learning solutions for classification problems. | X | X | X | X | X | X | X | 2.5 Sets a new goal for an existing AI algorithm |
| X | X | X | X | X | X | X | 1.6 Uses open-source AI application frameworks to build simple intelligent systems | X | X | X | X | X | X | X | 2.6 Uses existing AI technologies to develop new products |
| X | X | X | X | X | X | X | 1.7 Interprets the performance of an ML model (e.g., using a confusion matrix) | X | X | X | X | X | X | X | 2.7 Constructs and prepares a dataset for NLP processing |
| X | X | X | X | X | X | X | 1.8 Identifies whether various media products are GAN or not | X | X | X | X | X | X | X | 2.8 Creates a chatbot with appropriate human/bot interfaces |
| X | X | X | X | X | X | X | 1.9 Creates GANs in different subject areas (music, art, biology) | **3 AI development** | | | | | | | |
| | | | | | | | | X | | X | X | X | | | 3.1 Works as part of a team |
| X | X | X | X | X | X | X | 1.10 Creates a story and illustrations using GANs | X | X | X | X | X | X | | 3.2 Uses design thinking methodology to implement a project as part of a team |
| | | | | | | | | | | | | X | X | | 3.3 Creates innovative solutions through AI tools |
| | | | | | | | | | | | | X | X | | 3.4 Manages a technology-development project |
| | | | | | | | | | | | | | | | 3.5 Verifies the correctness of the technological solutions applied |

**Table 7**

Based upon Section 2 of the 'Skills Outcome Mapping' (p. 42 - 43) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

| SKILLS OUTCOME MAPPING Section 3 - Ethics and Social Impact | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 AI Applications** | E | S | W | N | M | A | I | **3 Social Implications of AI** |
| X | X | X | X | X | X | X | 1.1 Uses algorithms to produce art, music, etc. | | | X | X | X | X | X | 3.1 Properly disposes of technology |
| | | | | | | | **2 Ethics of AI** | X | X | X | X | X | X | X | 3.2 Identifies deepfakes (independently and with AI) |
| | X | | | | | | 2.1 Protects personal data and own/others' privacy | X | X | X | X | X | X | X | 3.3 Recognizes developments that pose a threat to equal opportunities in the use of IT and identifies options for action |
| X | X | X | X | X | X | X | 2.2 Identifies instances of bias in AI algorithms | | | | | | | | |
| X | X | X | X | X | X | X | 2.3 Identifies the stakeholders/beneficiaries of an AI algorithm | X | X | | | | | | 3.4 Compares, analyses and evaluates information and digital content critically (e.g. to recognize manipulation) |
| X | X | X | X | X | X | X | 2.4 Builds an ethical matrix for an algorithm (stakeholders and their values) | X | X | X | X | X | X | X | 3.5 Avoids health risks and threats to physical and mental well-being related to IT |
| X | X | X | X | X | X | X | 2.5 Researches exposed private data on the internet | X | X | X | X | X | X | X | 3.6 Helps shape social development by participating in public discourse |
| X | X | | | | | | 2.6 Manages digital identities and reputations and demonstrates an understanding of digital footprints | | | | | | | | |
| X | X | X | X | X | X | X | 2.7 Queries messy data in a table, and find bias | | | | | | | | |
| X | X | X | X | X | X | X | 2.8 Undertakes self-advocacy and redress (e.g. if rights are violated) | | | | | | | | |
| X | X | X | X | X | X | X | 2.9 Designs an end-to-end ML process that maximizes transparency and ensures fairness | | | | | | | | |
| X | X | X | X | X | X | X | 2.10 Writes guidance for AI developers to ensure to ensure that AI is made ethically | | | | | | | | |

**Table 8**

Based upon Section 3 of the 'Skills Outcome Mapping' (p. 42 - 43) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

| KNOWLEDGE OUTCOME MAPPING Section 1 - AI Foundations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Algorithms** | E | S | W | N | M | A | I | |
| | | | | | | | **1.1 Computational thinking** | | | | | | | | **2.2 Representations and simulations** |
| | | | | | | | 1.1.1 Understands abstraction | | | | | | | | 2.2.1 Understands rule-based reasoning |
| | | | | | | | 1.1.2 Understands decomposition | | | | | | | | 2.2.2 Develops an awareness of iterative |
| | | | | | | | 1.1.3 Explains the roles of decomposition, abstraction, pattern recognition and algorithms in computation | | | | | | | | processes in creating artefacts |
| | | | | | | | 1.1.4 Discovers commonalities and rules (patterns) in instructions | | | | | | | | 2.2.3 Develops knowledge of simulations/ models/computational abstractions of real-world physical systems |
| | | | | | | | **1.2 Algorithm definitions and applications** | X | X | X | X | X | X | | 2.2.4 Reflects on the limits and possibilities of simulations |
| | | | | | | | 1.2.1 Understands what algorithms are and do | | | | | | | | **3 Contextual problem-solving** |
| | | | | | | | 1.2.2 Understands that learning algorithms are sets of instructions created by humans to modify an input to create an output | X | X | X | | X | X | X | 3.1.1 Discusses and assesses the power and applicability of various AI approaches to practical problems |
| X | X | X | X | X | X | X | 1.2.3 Identifies examples of types of algorithms (classifiers, generators, regression) | | | | | | | | **4 Data Literacy** |
| | | | | | | | 1.2.4 Recognizes and describes everyday applications of algorithms | X | X | X | X | X | X | X | 4.1.1 Understands data trends |
| | | | | | | | 1.2.5 Recognizes the importance of algorithms in automated digital processes | | X | | | | | | 4.1.2 Understands the principles and processes of data collection and simple analysis |
| | | | | | | | **1.3 Algorithms components and processes** | X | | | | | | | 4.1.3 Understands how to collect, process, analyse, and report using data |
| | | | | | | | 1.3.1 Understands the parts of an algorithm (input, steps to change input, output) | X | X | X | | | | | 4.1.4 Understands the types of sources of information |
| X | X | X | X | X | X | X | 1.3.2 Understands the process of training, testing and deploying algorithms | X | X | X | X | X | X | X | 4.1.5 Describes the basic structure of a table in a spreadsheet |
| | | | X | | | | 1.3.3 Compares and contrasts the searching and sorting of algorithms | | | | | | | | 4.1.6 Describes the characteristics of data and information |
| | | | X | | X | | 1.3.4 Analyses the flow of execution of a recursive algorithm | | X | | | | | | |
| | | | | | | | | X | X | | | X | | X | 4.1.7 Assesses the capabilities of big-data management (e.g. warehousing processes) |
| X | X | X | X | X | X | X | 1.3.5 Understands regression algorithms | | | | | | | | |
| | | | X | | | X | 1.3.6 Compares how advanced data structures are used by algorithms | X | X | X | | X | | X | 4.1.8 Discusses the advantages and disadvantages of big-data cloud storage |
| | | | | | | | **2. Programming** | | | | | | | | 4.1.9 Compares structured and unstructured data |
| | | | | | | | **2. Programming** | | | | | | | | |
| X | X | X | X | X | X | X | 2.1.1 Develops knowledge of block-based and other programming tools | | | | | | | | 4.1.10 Explores encoding techniques to represent data efficiently |
| | | | | | | | 2.1.2 Knows different programming languages and production processes | X | X | X | | X | X | X | 4.1.11 Develops an awareness of how the transformation and presentation of of large datasets through visualization/ modelling can be used for decision-making |

**Table 9**

Based upon Section 1 of the 'Knowledge Outcome Mapping' (p. 39 - 41) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

| KNOWLEDGE OUTCOME MAPPING Section 2 - Understanding, Using and Developing AI | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 AI techniques** | E | S | W | N | M | A | I | **2 AI technologies** |
| | | | | | | | **1.1 AI definitions and components** | | | | | | | | **2.1 Computer and human perception** |
| X | X | X | | X | X | | 1.1.1 Understands 'weak' and 'strong' AI | X | X | | X | X | X | X | 2.1.1 Compares computer and human perception |
| X | X | X | | X | X | | 1.1.2 Describes basic terms related to AI | X | X | | | X | X | X | 2.1.2 Understands computer recognition |
| X | X | X | | X | X | | 1.1.3 Understands what AI is (and what it is not) | X | X | X | X | X | X | | 2.1.3 Understands methods of measuring with sensors |
| X | X | X | | X | X | | 1.1.4 Understands the parts of AI (dataset, learning algorithm, prediction) | X | X | X | X | X | X | | 2.1.4 Understands the role of sensors in data collection |
| X | X | X | | X | X | | 1.1.5 Understands and uses basic and general terms related to AI and machine learning | X | X | X | | X | X | | 2.1.5 Understands the difference between AI and human intelligence |
| | | | | | | | | | | | | | | | **2.2 Understanding technologies** |
| X | X | X | | X | X | | 1.1.6 Describes the basic features of AI | X | X | X | | X | X | X | 2.2.1 Explores AI technology and tools (e.g. classifier) |
| | | | | | | | 1.1.7 Understands that AI has underlying algorithms | X | X | X | | X | X | X | 2.2.2 Understands the processes of creating and using NLP |
| X | X | X | | X | X | X | 1.1.8 Understands convergence in AI | X | X | X | | X | X | X | 2.2.3 Explores the principles of data for NLP processing |
| | | | | | | | **1.2 Data use in AI** | | X | | | X | | X | 2.2.4 Understands autonomous systems |
| X | X | X | | X | X | | 1.2.1 Explains how data is used to make predictions | X | X | X | X | X | X | X | 2.2.5 Understands recommender systems and the technology behind them |
| X | X | X | | X | X | X | 1.2.2 Describes the flow of data through a deep learning network for classification problems | X | X | X | X | X | X | X | 2.2.6 Understands the process of creating and using computer vision |
| | | | | | | | **1.3 History of AI** | | | | | | | | **3 AI development** |
| X | X | X | | X | X | | 1.3.1 Knows the history of AI and its development over time | X | X | X | | X | X | X | 2.2.7 Develops an understanding of advanced technologies (IoT, cloud computing) |
| X | X | X | | X | X | | 1.3.2 Understands different approaches to developing AI | X | X | X | X | X | X | X | 2.2.8 Compares and contrasts an IoT device operating system with a typical desktop OS |
| | | | | | | | **1.4 Understanding how AI works** | | | | | | | | **3.1 Design thinking** |
| X | X | X | | X | X | | 1.4.1 Explains types of AI techniques and how they work (supervised, unsupervised, reinforcement, ML/DL) | | | | | | | | 3.1.1 Understands design thinking |
| | | | | | | | | | | | | | | | **3.2 Product development** |
| X | X | X | | X | X | X | 1.4.2 Understands how neural networks work and their parts (feed forward, evaluation of a prediction for accuracy, back propagation) | | | | | | | | 3.2.1 Understands the product development cycle |
| X | X | X | | X | X | X | 1.4.3 Understands the concepts and challenges of artificial general intelligence | | | | | | | | |
| X | X | X | X | X | X | X | 1.4.4 Knows how GANs work and identifies their parts | | | | | | | | |
| | X | X | | X | X | | 1.4.5 Explains heuristic searches and how they work | | | | | | | | |

**Table 10**
Based upon Section 2 of the 'Knowledge Outcome Mapping' (p. 39 - 41) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I).

**Knowledge:** The data in Tables 9 to 11 shows a consistent lack of coverage of advanced AI concepts such as machine learning and the application of algorithms in everyday contexts. This uniform weakness suggests that while foundational CS concepts might be addressed, there is a significant need for curricular updates to incorporate more advanced AI topics. Without these updates, students in these regions might be under prepared for future advancements and careers in AI-related fields, as well as for understanding and addressing the profound impact AI has on society. In this area, the 'Digital Technology' curriculum from Northern Ireland addresses more AI LOs than those of the other six regions (particularly in the areas "Understanding, Using, and Developing AI" and "Ethics and Social Impact" - Table 10 and 11).

## 5. Conclusion

The study presented in this paper contributes to global AI education by supporting the development of effective AI content and teaching strategies in upper secondary education. Our analysis highlights the widespread absence of key AI learning outcomes—such as those related to advanced data structures, ethical considerations, and practical applications—in national curricula, which raises concerns. In every region, crucial knowledge, skills, and values & attitudes relating to the social implications of AI is also missing, which underscores the necessity for curriculum updates to ensure students are adequately equipped with essential AI knowledge and skills, preparing them for the evolving technological landscape. This paper highlights a lack of uniformity in the approach to AI education across these 7 regions, with a particular need for enhanced focus on the practical, social and ethical dimensions of AI technologies.

| KNOWLEDGE OUTCOME MAPPING Section 3 - Ethics and Social Impact | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFICATIONS | | | | | | | LEARNING OUTCOMES | SPECIFICATIONS | | | | | | | LEARNING OUTCOMES |
| E | S | W | N | M | A | I | **1 Applications of AI to other domains** | E | S | W | N | M | A | I | **2.6 Transparency/explainability** |
| | X | X | | X | X | | 1.1.1 Identifies/explains AI use cases and applications in everyday life | X | X | X | X | X | X | X | 2.6.1 Understands the mechanisms of image data manipulation |
| X | X | X | | X | X | | 1.1.2 Describes how AI drives many software and physical systems | X | X | X | X | X | X | | 2.6.2 Understands the principle of explainable AI and its tenets |
| X | X | X | | X | X | | 1.1.3 Understands new advances and applications of AI | | | | | | | | **2.7 Human agency** |
| X | X | X | | X | X | | 1.1.4 Knows important areas of application in the AI and information technology professions | | X | X | | X | X | | 2.7.1 Understands that humans control AI and machine learning |
| | | | | | | | **2 Ethics of AI** | | | | | | | | 2.7.2 Understands usability, security, and accessibility of computer systems as key features of their design |
| | | | | | | | **2.1 Ethical terms, definitions and examples** | X | X | X | | X | X | | 2.7.3 Understands how to ethically create and/or use AI |
| | X | X | | X | X | X | 2.1.1 Understands what ethical terms such as 'bias', 'fairness' and 'representation' mean in relation to AI | | | | | | | | **3. Social implications** |
| | | | | | | | | | | | | | | | **3.1 AI's advantages and disadvantages** |
| | X | | | X | X | | 2.1.2 Reflects on human rights and ethical issues in technology/AI use | | | | | | X | | 3.1.1 Understands how AI can benefit humans |
| | | | | | | | | | | | | | X | | 3.1.2 Reflects on the advantages and disadvantages of new technologies |
| | X | X | | X | X | | 2.1.3 Describes the limitations of AI | | | | | | | | |
| | X | | | X | | | 2.1.4 Understands the ethical considerations and dilemma which may arise from AI | | X | | | X | X | | 3.1.3 Outlines the advantages and disadvantages of AI in different social, educational, and professional contexts |
| | | | | | | | **2.2 Access** | | | | | | | | |
| | X | X | | X | | | 2.2.1 Understands issues of access to technology | | | | | | | | **3.2 AI in everyday life and work** |
| | | | | | | | **2.3 Bias** | | | | | | | | 3.2.1 Considers the role, importance and/or impact of new technologies on society (life, work and education) |
| X | X | X | | X | | X | 2.3.1 Explains how the biases of the programmers influence the fairness of the AI rules | | | | | | | | |
| X | | X | | | | | 2.3.2 Understands the effects of information quality in decision-making | | | | | | | | 3.2.2 Explores emerging technologies that have the potential to disrupt the way people live, learn and work |
| X | X | X | | X | X | X | 2.3.3 Understands algorithmic bias and types/sources of bias | | | | | | | | 3.2.3 Develops an awareness of digital citizenship |
| X | X | X | | X | X | X | 2.3.4 Understands methods of mitigating/ lessening bias in AI algorithms | | | | | | | | 3.2.4 Understands how AI is changing jobs (even outside STEM) |
| X | X | X | | X | X | X | 2.3.5 Understands different types of bias (representation, selection, etc.) | | X | X | | X | X | | 3.2.5 Understands the benefits of and demands for STEM job |
| X | X | X | X | X | X | X | 2.3.6 Analyses cases where AI has been clearly fair or unfair | | | | | X | X | X | 3.2.6 Recognizes the interactions between nature, technology and society |
| | | | | | | | **2.4 Intellectual property** | | | | | | | | **3.3 Environmental impacts** |
| | X | | | X | | X | 2.4.1 Understands intellectual property rights | | X | X | X | X | | X | 3.3.1 Understands the positive and negative environmental impacts of technology |
| X | X | X | X | X | X | X | 2.4.2 Defends a position on ownership of art generated or enhanced by AI | | X | X | | X | | X | 3.3.2 Knows the computational and environmental costs of generating AI |
| | X | X | | X | | X | 2.4.3 Understands/respects basic intellectual property laws | X | X | X | | X | | X | 3.3.3 Understands how computational and environmental costs can be reduced (more efficient models, evaluation of costs and benefits) |
| | | | | | | | **2.5 Privacy and security** | | | | | | | | |
| | X | X | | | | | 2.5.1 Develops an awareness of cybersecurity | | | | | | | | |
| | X | | | | | | 2.5.2 Develops deep knowledge of the concept of digital identity | X | X | X | | X | X | X | 3.3.4 Understands how computational and environmental costs lead to inequity in developing AI |
| | X | X | X | X | X | X | 2.5.3 Understands how digital service providers inform users about how personal information is used | | | | | | | | **3.4 Fakes and misinformation** |
| | | | | | | | | X | X | X | X | X | X | X | 3.4.1 Reflects on positive/negative aspects and social consequences of deepfakes |
| | X | | | | | | 2.5.4 Understands how personally identifiable information can be used and shared | X | X | X | X | X | X | X | 3.4.2 Reflects on the social implications of GAN technology (e.g. fake homework) |
| | | | | | | | | X | X | X | X | X | X | X | 3.4.3 Knows the six key features of misinformation * |
| | | | | | | | | X | X | X | | X | | X | 3.4.4 Understands how misinformation spreads |
| | | | | | | | | | | | | | | | **3.5 Gender** |
| | | | | | | | | X | X | X | X | X | X | X | 3.5.1 Develops an awareness of gendered consequences/opportunities in technology |

**Table 11**
Based upon Section 3 of the 'Knowledge Outcome Mapping' (p. 39 - 41) table in the UNESCO [1] AI curricula mapping framework. An X indicates whether the learning outcome is absent (neither expressly nor implicitly included) from selected upper secondary computer science specifications of England (E), Scotland (S), Wales (W), Northern Ireland (N), Malta (M),Western Australia (A) & Ireland (I). * 3.4.3 - Cited by the MIT DAILy Curriculum as: 'Invokes emotion; polarization; spreading conspiracy theories; deflecting blame; impersonating or fake accounts; and "trolling" people online'

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