

The importance of TVET students' critical and flexible thinking skills for AI competence

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October 2023

Introduction

Artificial Intelligence (AI) is rapidly and relentlessly penetrating life in societies, workplaces, and education institutions worldwide. Technical and Vocational Education and Training (TVET) which in the main prepares students for intermediate level jobs and tasks, operates in an area where AI is increasingly automating repetitive workplace tasks. The reality in this context is that workers for their own survival need to be flexible in approach and so open to workplace changes including opportunities for career variation. It is thus incumbent on TVET educators to prepare their students with the skills that will support flexibility in thinking. This underpins their adjustment in the rapidly changing, dynamic, AI-infused work environment.

As such, TVET programmes should foster in students new skills in understanding and working with AI, but also their development as lifelong learners through what are termed as 'transversal' skills (Nuthall, 2023). Operating within and alongside technical skills such as mathematics, computer and technical design skills, these assist workers to be dynamic, capable of adapting to change quickly, and so able to '*identify and exploit career pathways opportunities*' (UNESCO, 2014, p.15). Significant transversal skills include **flexible and critical thinking**, which assists individuals to address issues and problems in a changing, AI-infused world.

Digital Competence Frameworks (DCFs) present analytical and systematic structures of digital skills required for particular community, industrial and occupational roles and can be of benefit for TVET educators. The UNESCO-UNEVOC website '[Digital Competence Frameworks for Teachers, Learners and Citizens](#)' presents a [database of DCFs useful for TVET educators](#), and articles on 'hot topics' about digitalization and TVET. This article presents some existing DCFs relevant for TVET educators to prepare their students for the changing world of AI and technology. These support the development of students' critical thinking that underpins flexible work and cognitive approaches.

Artificial Intelligence (AI), the workplace and TVET

AI permeates today's world across many if not most societal functions. Common examples include AI for transit through digital maps: alternative routes to destinations are suggested by the AI app, and directions provided as the route is taken. Spam filtering on emails is done through AI and assistance with writing is provided via apps such as Grammarly and ChatGPT.

AI is significantly 'altering labour markets, industrial services, agricultural processes, value chains and the organization of workplaces in particular' (UNESCO-UNEVOC, 2021). It is increasingly prevalent across many workplace sectors, impacting heavily on TVET educators and programme curricula. For example, in the manufacturing workplace AI manages inventory and powers robots for tasks such as assembly and stacking. In health care medical doctors can work with AI to help them predict and diagnose diseases. UNESCO-UNEVOC (2021) reports that in 2021, 50% of organizations worldwide use some form of AI and 82% of middle skills jobs already require digital skills.

The need for flexibility in thinking underpinned by critical thinking is evident in the comprehensive and all-encompassing nature of AI. As automation through machines and computers that augments and even replaces human

intelligence, AI ‘mimics’ the human mind’s cognition to solve problems, make decisions and learn (IBM, Undated, <https://www.ibm.com/topics/artificial-intelligence>). That is, an AI system can understand and learn from external data and, with versatility, use it to perform tasks (Kaplan and Haenlein, 2019). This is seen in AI’s ability to predict, make recommendations and decisions by using algorithms that analyse the environment. It uses machine learning to learn from such data and variables, and through deep learning, create patterns and outcomes (Rouhiainen, 2018). TVET educators can prepare students for this constantly evolving and new world through not only teaching and assessing established industrial patterns and procedures, but through building in approaches that question why and how, and considering new ways of doing things.

TVET is a key educational area that promotes a nation’s socio-economic growth and development (UNESCO 2021). This underscores the need for progressive approaches that foster critical thinking, and appreciation of the dynamic nature of knowledge and practices (Maclean, 2013, cited in UNESCO, 2014). On the individual level, it positions students to survive and prosper in the rapidly changing, digitalized world, especially when AI is creating different forms and ‘new job opportunities’ (OECD, 2021) for individuals with dynamic approaches and outlooks. Critical thinking enables users to move beyond unquestioningly implementing information, but to engaging in inquiry through analyzing and evaluating information, reasoning, constructing ‘sound and insightful new knowledge, understandings, hypotheses and beliefs.’ (Heard, Scoular et al, 2020). These processes are the basis of application of information for informed decisions and effective problem-solving (Heard, Scoular et al, 2020), and for adaptation in the rapidly changing environment.

Skills to prepare TVET students for the AI-imbued workplace.

Alongside the technical skills and knowledge for TVET’s trade, vocation or industry area, students’ skills in critical thinking support flexibility and adaptability in the increasingly AI-infused workplace and complement their knowledge of how to use AI in their jobs. The question then is how can TVET educators build such skills into their programmes? TVET educators’ knowledge and skills become outdated quickly in the rapidly developing AI world (OECD, 2021, p.15), and they require Continuous Professional Development (CPD) to integrate and apply AI into teaching and learning. Students also require skills on how to use it in their learning.

Relevant digital competence frameworks (DCFs) can guide TVET educators in this regard. By identifying the components that make up particular skills and often providing performance indicators for these, DCFs assist TVET educators to break down the larger concept of flexibility and critical thinking into constituent parts. From these, the sub-skills appropriate for a programme and discipline can be selected, built into curricula, and modelled in the teaching process.

DCFs which include AI and critical thinking competencies for TVET

Using AI and working with it

Relevant resources that identify some general skills pertinent to AI and its workings are presented in Table 1 below. Particularly if they include performance indicators, they are useful for TVET educators to gauge their students and their own skill levels.

Table 1: Using/Working with AI

Name	Web Address	Contribution to AI skills development in TVET
Artificial Intelligence Competency Framework. A success pipeline from college to university and beyond	https://www.dawsoncollege.qc.ca/ai/wp-content/uploads/sites/180/Corrected-FINAL_PIA_ConcordiaDawson_AICompetencyFramework.pdf	Presents AI skills required across the domains of technology, business, and human areas.
Competencies for the artificial intelligence age: visualisation of the state of the art and future perspectives	https://link.springer.com/article/10.1007/s11846-022-00613-w	Systemises AI competencies for the present and the future. Includes a measurement analysis tool.
Digital Competences Framework (DigComp 2.2) update published	https://ec.europa.eu/social/main.jsp?langId=en&catId=89&newsId=10193&furtherNews=yes	Provides guidelines for educators to foster digital and data-related literacy.

1. Artificial Intelligence Competency Framework. A success pipeline from college to university and beyond.

Concordia University and Dawson College, September 2021.

https://www.dawsoncollege.qc.ca/ai/wp-content/uploads/sites/180/Corrected-FINAL_PIA_ConcordiaDawson_AICompetencyFramework.pdf

This resource presents a tool for educators, programme developers, recognition of prior learning coordinators and other curriculum and training programme developers that address the ever-evolving needs for AI talent. The AI competencies are clustered in the resource for varied education settings that include TVET. Sectioned into Technical, Business and Human domains, the technical domain includes performance indicators under the categories of data, mathematics and statistics, programming, machine learning, deep learning and infrastructure. The modular nature of the framework enables educators to integrate the domains, areas and indicators into program goals and objectives.

2. Competencies for the artificial intelligence age: visualisation of the state of the art and future perspectives.

Santana, M and Diaz-Fernandez, M (2022) Review of Managerial Science.

<https://link.springer.com/article/10.1007/s11846-022-00613-w>

Through a comprehensive literature review, this resource presents a systematic overview of the competencies and skills for AI. Recognising the key role of human resources in the development of AI competence, it includes a performance management analysis. The summary table of AI competencies derived from the literature includes, among others, information management and processing and meta cognitive and cognitive skills, including critical thinking. The value for TVET educators is the overview it provides of systems level skill areas for AI competence currently and for the future.

3. DigComp 2.2: The Digital Competence Framework for Citizens - With new examples of knowledge, skills and attitudes

<https://ec.europa.eu/social/main.jsp?langId=en&catId=89&newsId=10193&furtherNews=yes>

This resource recognises the power of emerging technologies such as AI, the internet of things (IoT), and datafication, as well as their green and sustainability aspects. It provides guidelines for teachers and educators to foster digital literacy, including data related skills. Usefully for TVET educators, this resource includes a comprehensive digital competence framework across the levels of **Foundation, Intermediate, Advanced** and **Specialised** that includes dimensions of these proficiency levels. Of practical value for TVET educators, it includes a thorough range of clear and measurable performance indicators.

Of the many DCFs available online, Table 2 below presents three that are useful for TVET educators in developing their students' critical thinking generally and specifically in AI use, as well as description and explanation of their value. Table 3 below presents some additional DCFs for exploration by TVET educators for critical thinking development.

Table 2: Critical Thinking Skills Development

Name	Web Address	Critical Thinking Development in TVET
Heard, Scoular et al, (2020) <i>Critical Thinking: Definition and Structure</i> , The Australian Council for Educational Research Ltd.	https://research.acer.edu.au/ar_misc/38/	Identifies major strands for critical thinking and explains cognition involved in each.
Artificial Intelligence & Digital Transformation Competencies for Civil Servants	https://unesdoc.unesco.org/ark:/48223/pf0000383325	Includes outline of complementary attitudes for effective digital transformation and AI Usage
Use, Understand, & Engage: A Digital Media Literacy Framework for Canadian Schools	https://mediasmarts.ca/sites/default/files/pdfs/digital-media-literacy-framework.pdf	Section for Grades 9 -12 students which in the main is relevant to TVET provides a road map for teaching critical and effective engagement with media

1. Heard, Scoular et al (2020), *Critical Thinking: Definition and Structure*, The Australian Council for Educational Research Ltd.

https://research.acer.edu.au/cgi/viewcontent.cgi?article=1039&context=ar_misc

This framework is useful for TVET educators in its identification of three major strands for critical thinking: Knowledge Construction; Evaluating Reason; Decision Making. Within these the Framework includes subsections with explanation of the cognition/mental activity involved. For example, for the Knowledge Construction strand, the components are students' ability to: (1) identify gaps in knowledge; (2) Discriminate amongst information; (3) Identify patterns in information and make connections. These components provide tangible functions to guide TVET educators in their

teaching and learning design for critical thinking. Importantly, these components embody valuable skills for students in the current world of social media.

2. Artificial Digital Intelligence and Digital Transformation: Competencies for Civil Servants.

<https://www.unesco.org/en/digital-competency-framework>

For TVET educators, this DCF is based on the understanding that the challenges of digitalization and AI require a new set of skills and competencies. It identifies and explains five complementary attitudes that underpin effective digital transformation and AI usage that are all relevant to the development and use of critical thinking. In particular these are the attitudes of: (1) **Adaptability**: the ability to work flexibly, to recover from failure, and to adapt quickly to unexpected events; (2) **Creativity**: able to explore innovative ideas and thus solutions; (3) **Curiosity**: awareness of the need to find new solutions in complexity and challenges; (4) **Experimentation**: the ability to apply and synthesize ideas across divergent fields, with a mind-set of openness. The value of this for TVET educators is that it enables them to appreciate the nature and subsets of critical thinking, again providing direction for curricula development.

3. Use, Understand & Engage: A Digital Media Literacy Framework for Canadian Schools

<https://mediasmarts.ca/sites/default/files/pdfs/digital-media-literacy-framework.pdf>

The section of this framework that is focused on years 9-12 is relevant to TVET educators; it enables them to support and teach their students how to engage with digital media in ways that are critical and effective for responsible use. It includes a range of teaching activities that can be adapted to more general aspects of contemporary life, assisting students to develop mindsets that are flexible and able to exercise critical judgement. This is the springboard for curiosity, exploration and creativity as required for the new world of AI.

Table 3: Other useful DFCs for critical skills development

Name	Web Address	Contribution to critical thinking skills development
Kamaruzaman, Hamid et al, (2022) Determination of 4IR Generic Skills Constructs for Engineering Graduates.	https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwigkO6yzcmEAXWoEGIAHeWIBTEQFnoECBEQAQ&url=https%3A%2F%2Fwww.journalppw.com%2Findex.php%2Fjpsp%2Farticle%2Fdownload%2F1364%2F694&usg=AOvVaw38IaP3otxJ6gbT2jEEB2Ik&opi=89978449	Includes table and breakdown of skills for critical thinking, problem solving, creativity, and adaptability (amongst others) for Engineering students
International Society for Technology in Education (ISTE)	https://www.iste.org/standards/iste-standards-for-students	Includes sections and sub sections with functions for areas including knowledge construction, innovative design, computational thinking, creative communication and global collaboration.
Digital Competency Framework, Quebec (2019)	http://www.education.gouv.qc.ca/fileadmin/site_web/documents/ministere/Cadre-reference-competence-num-AN.pdf	Provides a framework to develop critical thinking in digital technology use, along with other areas including innovation and creativity, problem solving and provides concrete classroom activities.
Australian Curriculum, Assessment and Reporting Authority (ACARA)	https://www.australiancurriculum.edu.au/f-10-curriculum/general-capabilities/critical-and-creative-thinking/	Focuses on developing critical thinking and creativity in the Australian education curriculum. Circular processes are analysing, synthesising and assessing; reflecting on thinking processes; inquiring and organising information/ideas.

1. **Determination of 4IR Generic Skills Constructs for Engineering Graduates.** (Kamaruzaman, Hamid et al, 2022) Journal of Positive School Psychology, 6 (3). <http://journalppw.com>

While focussed on the engineering field which forms a substantial part in TVET programs, this framework is useful for TVET in general; it outlines required generic skills for graduates in the IR4 environment. In highlighting critical thinking skills as one of the required skills, the framework places critical thinking into an ecosystem so TVET educators can appreciate it as part of a skill bundle. Thus, in curricula critical thinking can be cross-linked with other skills.

2. **International Society for Technology in Education (ISTE)**
<https://www.iste.org/standards/iste-standards-for-students>

This framework includes a section to empower students for a student-driven process. It includes an e-book to assist educators to use the standards in the classroom. Section 1.3, Knowledge Construction, provides performance indicators to guide TVET educators in developing and critically assessing students' skills curating resources with digital tools.

3. **Digital Competency Framework, Quebec (2019)**
http://www.education.gouv.qc.ca/fileadmin/site_web/documents/ministere/Cadre-reference-competence-num-AN.pdf

This framework develops users' digital competency and equips them with skills including confidence and critical and creative thinking in using digital technologies to achieve objectives. For example, it supports them to select the best digital tools for a particular task, and focuses on skills to assess new technologies critically and to adapt, adopt and implement these for the user's purposes.

4. **Australian Curriculum, Assessment and Reporting Authority (ACARA)**
<https://www.australiancurriculum.edu.au/f-10-curriculum/general-capabilities/critical-and-creative-thinking/>

This framework explains that explicit teaching and embedding of critical and creative thinking in learning enables students to use logic and imagination to reflect on how to address issues, tasks and challenges. This provides the background for students' flexibility as seen in their ability to select from a range of thinking strategies and use them selectively in various contexts. The attachment to this framework, '*Critical and Creative Thinking Continuum*', includes relevant skills and sub skills across a range of levels that could support TVET educators to develop their students critical thinking and thus their flexibility.

Conclusion

The advancement of AI and digitalization impacts irrevocably on TVET educators as they prepare their students for their future work and personal lives. Underpinning such preparation is the need to develop their students' skills in understanding and working with AI and digitalization, as exemplified in the DCFs included in this article. Complementing this is the need to develop students' capacity for critical thinking. In practical terms, this means that workers can not only apply skills they have been taught, but that they are equipped with the ability to think and analyze further than skill application. Critical thinking as seen in the DCFs discussed in this article supports students to be more open-minded and flexible in thinking through their ability to analyze, synthesize and evaluate information and ideas in the process of making decisions and solving problems. Critical thinking is vital for students in today's rapidly and incessantly changing world where career directions and jobs must be malleable and able to adapt.

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