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Exploring digital literacy in the era of digital civilization: A framework for college students in China

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Abstract. Cultivating the digital literacy of all citizens, especially for college students, would contribute to the construction of a 'Learning Society' where everybody loves learning and would offer a powerful impetus for building a modern country. First, this paper reviews the origins and general definitions of computer literacy, network literacy, media literacy, information literacy and digital literacy. Compared with similar terminologies, digital literacy features the subjective initiatives to actively improve one's and others' skills, competence, awareness and thinking mode for adapting to, qualifying for and creating a new digital age and society. Second, the internal logic in the Digital Literacy Framework of College Students (DLFCS) can be summarized as 'Skills-Competencies-Awareness' attributing to the evolution progress of 'digital technologies utilization, actual problems solving, and digital awareness cultivation'. Following this logic, this paper develops the DLFCS through scene-based requirements analysis and professional consultations, including three areas (i.e. operational skills, applied competencies, thinking & awareness), identifying fifteen descriptors and their examples with key performances. Third, it measures the self-perception and actual performance of college students digital literacy by questionnaire, Q&A tests and task evaluation, and validates the completeness and validity of the DLFCS by Pearson correlation analysis of datasets collected in three modes. The results indicate that (a) the fifteen descriptors in DLFCS basically cover the essential areas of digital literacy with extremely weak correlations among them, (b) the relationships of progressive and intertwined 'Skills-Competencies-Awareness' demonstrate the validity of the internal logic and DLFCS itself, (c) to be digitally literate requires long-term and gradually-progressed cultivation and improvement, as achieving one descriptor of digital literacy proficiently does not guarantee good performance on the other descriptors.

Keywords: Digital literacy framework, internal logic, literacy descriptors, self-perception, actual performance, correlation analysis

1. Introduction

The concept of the "Metaverse" has gained popularity, describing a future world where virtuality and reality are intertwined through advanced technologies like digital twins, extended reality, blockchain, and more. This has led to new social relations and a significant shift in thinking, working patterns, and life philosophy. Traditional key competencies in human relations and physical environments, like reading,

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writing, and social skills, are no longer enough to efficiently participate in social activities amid increasing needs. Hence, mastering the abilities of discovering, identifying, and processing digital resources is crucial to adapt to the rapid development of a digital civilization.

The COVID-19 pandemic was recently shutting down the world, which had caused a tsunami across all societal sectors (from an individual's private life to organizations and the government) [1]. It forced governments worldwide to accelerate digital transformation, develop digital economies, and enhance national competitiveness by improving citizens digital literacy. China's government has prioritized the construction of "Digital China" since the 18th National Congress of the Communist Party of China. In March 2021, 'The Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China' suggested that digital skills education and training should be boosted to promote the digital literacy of the general public [2]. Then, the 'Action Plan for Enhancing Citizens Digital Literacy and Skills' (abbreviated as 'Action Plan' hereinafter) published in November 2021 set the goal that Chinese citizens digital literacy and skills would reach the level of developed countries by 2035 [3].

Teaching about digital awareness, digital literacy, lifelong learning abilities, and a sense of social responsibility contributes to narrow the digital divide that is growing along racial and ethnic lines [4], to construct a "Learning Society" where everybody loves learning, and to offer a powerful impetus for building a modern country. This paper aims to provide intellectual support and practical experience for digital literacy cultivation, bridging the digital divide, and empowering social development based on the development and evaluation of the Digital Literacy Framework of College Students (DLFCS).

2. Definition of digital literacy and other similar terminologies

Before the emergence of 'Digital Literacy', academia used the terms of 'Computer Literacy', 'Network Literacy', 'Media Literacy', 'Information Literacy' or their combination to describe the functional literacy beyond reading & writing. Actually, there were two main explanations for computer literacy after its appearance in 1970s. Some scholars like Luehrmann [5], Tobin [6], et al. regarded it as the ability to do computing and mathematics in the new era. It means people should practice thinking about and representing a problem, writing his/her thoughts down, studying and criticizing the thoughts of others, and rethinking and revising their ideas. Other scholars like Anderson [7], Noble [8], et al. explained it as a new literacy derived from the traditional ability of reading & writing, which highlighted the social component of preparation for inevitable changes to take place in the computer revolution. In the 1990s, the content of computer literacy was gradually covered by network literacy and concentrated on the knowledge and skills of computing, reading & writing with computers, like programming and algorithms, due to the rapid development of the Internet.

In 1993, Charles R. McClure introduced a new term, network literacy, into the confusing array of literacy notions, referring to the ability to identify, access and use electronic information from the network [9]. To be network literate not only requires learning how to manipulate various devices and applications, but also to understand how to discover valuable resources through those platforms to improve work efficiency and life quality. However, applicable laws, regulations, governance measures and morality rules has not kept up with the rapid development of the Internet, which has bred a growing amount of cyber crimes, bullying and ideological infiltration in recent years. Thus, network literacy expands into protecting personal safety and defending cyberspace security, in order to eliminate ignorance, prejudice and other vile conduct to build a peaceful and interdependent community with a shared future in cyberspace.

Media literacy was initially explained in the U.S. National Leadership Conference on Media Literacy, 1992 as the ability of a citizen to access, analyze and produce information for specific outcomes. The fundamental objective of media literacy is to promote critical autonomy in relationship to use of all media, and emphases including informed citizenship, aesthetic appreciation and expression, social advocacy, self-esteem and consumer competence [10]. Differing from computer literacy and network literacy that study the procedure of computers and Internet usage, media literacy pays close attention to the communication content and its related details on all media, such as tools (television, Internet, etc.), information, and strategies. Digital channels has the unique capacity to combine mass forms of communication through media convergence by engaging users in interpersonal interactions [11]. Media literacy are transformed to focus on the culture expression and engagement, and critical thinking on the content elements (letters) and grammar elements (polygons) in the media environment, according to the theory of participatory culture claimed by Jenkins [12] and the model of multiple media literacies outlined by Meyrowitz [13].

The history of information literacy cannot be told without correlating it with the library education proposed by American librarian Dewey [14]. After that, such bibliographical instructions had been continuously carried out within university campuses until Paul G. Zurkowski first explained that people learned techniques and skills for utilizing the wide range of information tools as well as primary sources in molding information solutions to their needs could be characterized as information literates [15]. There are three essential facets about information literacy, namely recognizing information needs, evaluating information and effectively using them [16], which prepare one's lifelong learning. Theoretically, information literacy can cover the scope of all literacy notions relating to information itself, accounting for information is basically involved in all social behaviour. In fact, information literacy is contrarily limited to the domain of learning and research and is a collection of knowledge and skills on information seeking, evaluation and utilization.

In 1995, Richard A. Lanham defined digital literacy as the ability to understand information which was increasingly presented in the new format blending words with recorded sounds and images into a rich and volatile mixture [17]. Nevertheless, the subsequently created literacy notions, such as digital information literacy [18], digital media literacy [19], E-literacy [20] and multimodal literacy [21], caused miscellaneous confusions on the concept of digital literacy. This paper identifies three primary criteria to judge the definition of digital literacy:

(a) Digital literacy is definitely not a notion trick via random combination of similar words, while digital information literacy, digital media literacy, e-literacy and multimodal literacy cannot convey the implications and value of digital literacy.
(b) Digital literacy does not equal to a combination of just information literacy, media literacy, network literacy, computer literacy, while it is an obvious misinterpretation to easily enumerate the elements from these literacy notions.
(c) Digital literacy ought to be a dynamic convergence of complex literacies across multi-disciplines that are newly developed or refined from existing literacy notions, including the skills, competence, awareness and thinking modes that are helpful for creating a glorious and sustainable society.

Consistent to the criteria above, this paper is highly supportive of two kinds of statements on the definition of digital literacy. The first one is 'Digital literacy is the awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyse and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action and to reflect upon this process.' proposed by Martin [22]. The second one is 'Digital

literacy and skills are a series of literacies and competencies (i.e. the adaptability, competency and creativity) needed in the digital learning, working and life for digital citizens, which encompass digital accessing, production, manipulation, evaluation, interaction, sharing, innovation, safety, ethics, etc.' from 'Action Plan' [3]. Compared with information literacy, media literacy, network literacy, computer literacy, etc., digital literacy features the subjective initiatives to actively improve one's and others' skills, competence, awareness and thinking mode for adapting to, qualifying for and creating a new digital age and society.

3. Digital literacy frameworks and evaluation

In 2002, Yoram Eshet-Alkalai proposed a terminology framework of digital literacy, i.e. photo-visual literacy (reading instructions from graphical interfaces), reproduction literacy (utilizing digital reproduction in learning), lateral literacy (constructing knowledge from non-linear navigation), and information literacy (evaluating information) [23]. Two years later, the term of lateral literacy was replaced by branching literacy, and socio-emotional literacy was added as the fifth dimension to describe the ability to avoid 'traps' as well as derive benefits from the advantages of digital communication [24]. In 2012, it was updated with the final dimension (real-time thinking skill) that meant the ability to process large volumes of fast-moving stimuli at the same time, as in video games or in online teaching [25]. This framework has presented constructive guidance and reference for the development of frameworks at regional, national or sub-national levels from then on. Many similar frameworks had been proposed for different purposes. For example, Reddy et al. developed a new innovative digital literacy framework that were integrated into the existing and future education frameworks to assist educationists in narrowing the digital skills gaps and preparing graduates for the work sector [26]. Unfortunately, these frameworks seem actually conceptual models and are unfriendly towards mapping the clear-cut descriptors.

The first comprehensive and widely recognized framework is 'The Digital Competence Framework for Citizens, DigComp 1.0', developed by the Information Society Unit at JRC-IPTS (Joint Research Centre, Institute for Prospective Technological Studies) on behalf of the European Commission, DG Education and Culture [27]. The shell of DigComp is structured in five dimensions, including areas, descriptors, proficiency levels, examples of the knowledge, skills and attitudes, and applicability of the competence for learning and employment. DigComp 1.0 was upgraded to version 2.0 [28] with a revision of the vocabulary and more streamlined descriptors in 2016 (see Appendix A). The dimensions of proficiency, knowledge, skills and attitudes, and learning and employment were respectively modified in DigComp 2.1 [29] and 2.2 [30]. In 2018, UNESCO Institute for Statistics built on DigComp 2.0 as the initial framework and conducted empirical studies to develop the Digital Literacy Global Framework (DLGF), while adding two areas (0. Devices and software operations and 6. Career-related competences) and five descriptors (including 5.5 Computational thinking) [31].

Different from the substantial research findings in Western countries, China has not published the official digital literacy framework or standard yet. There are only 869 journal papers, dissertations and proceedings, according to the keywords search on the China National Knowledge Infrastructure (CNKI)[1] as of April 10th, 2023. 42.7% of those articles are reviews of foreign research findings. For example, Ren, et al. introduced the content of DigComp 1.0 and its empirical studies of educational policy making

[1]CNKI is the largest academic search engine in China, similar to Clarivate Web of Science.

and scientific decision-making methodology, which were expected to offer valuable reference for the development of digital competence in China [32]. Besides, Jiang, et al. summarized the difficulties in promoting citizens digital literacy and constructed a digital literacy model of 'Perception, Circulation, Absorption, Innovation and Advancement' on the basis of an epistemic logic 'mental access → material access → skills access → usage access' [33]. Huang addressed a digital literacy model for college students in engineering departments who were broadly good at logic reasoning, which contained three dimensions (fundamental mathematical literacy, specialized discipline literacy and interdisciplinary digital literacy) and four areas (morality and safety, communication and collaboration, knowledge and skills, thinking and cognition) [34]. Evidently, the research on the definition and framework of digital literacy is quite limited, and most domestic frameworks or models are short of descriptors/indicators and examples/applicability.

Huang's investigation of the digital literacy of 883 college students showed that most Chinese students had poor performance on information searching, content creation, emotional expression, safety awareness and self-innovation [35]. Both sophisticated domestic frameworks and integrated evaluation standards of digital literacy are required to identify individual differences and launch targeted training programs. The studies of digital literacy evaluation in China are more abundant than those of definition and framework. For example, Gu, et al. operated a fuzzy evaluation for college students digital literacy in the Jilin Province, China, using a five-dimensional framework to design the evaluation questionnaire [36]. Hu, et al. constructed an evaluation index system by selecting indicators from digital competence and digital awareness, and measured the digital literacy scores of Chinese residents based on data from the China Household Tracking Survey (CFPS) [37]. In contrast with the self-efficacy questionnaire applied in all Chinese evaluation studies (also common in Western countries), particular tasks are employed to observe the actual performance of subjects in the digital environment. One example is the examination of socio-emotional literacy enabled in the learning activities during the annual 'Internet safety week' of Israeli elementary and middle schools [38]. Two raters would code the posts and grade the emotional expression, open communication and group cohesion using a quantitative content analysis technique [39], when students were asked to think about positive and negative aspects of 'online safety', provide examples, and express their opinions in an asynchronous discussion group. The other example refers to the assessment of photo-visual literacy. Each participant was allowed to create a theater stage using a multimedia computer program they had never used before, called Opening Night [40]. Outcomes would be assessed and graded according to completeness and complexity of the theater stage, including the overall setting, the characters, their features, affinities, costumes, and the text they say [40].

In summary, the objectives of this paper are to develop a comprehensive and rational framework for domestic college students with precise descriptors and examples, and to demonstrate its completeness and validity by Pearson correlation analysis of the evaluation data sampled in the modes of questionnaire (self-perception), Q&A tests, and task evaluation (actual performance), for filling the relevant lacunae and promoting the theoretical research of digital literacy in China.

4. Development of the digital literacy framework of college students

4.1. The internal logic of framework

In general, the definition of a certain terminology is a macroscopic statement in one or several paragraphs. The framework looks like a manual with unambiguous instructions. It often consists of

multiple dimensions reflecting a different stage of granularity, such as areas, descriptors and examples. Areas are typically short definitions of the competence/awareness categories, descriptors are detailed sub-competence or sub-awareness within areas, examples are the knowledge, skills and attitudes related to each descriptor, or how the competence/awareness could be applied to real-life purposes. As a consequence, such umbrella-structured frameworks are more understandable and acceptable than the tedious definition statements. After a careful and thorough literature review, many limitations for present frameworks over the world still exist, such as indicators omission, content overlap and expression ambiguity. The root cause is the deficiency and incoherence of the internal logics that determine the framework completeness and validity. For instance, area 1. information and data literacy, 2. communication and collaboration, and 3. digital content creation in DigComp are rather linear [27], which means they can be re-traced in terms of simple conducts, like searching information, sharing information and creating contents. Area 4. safety and 5. problem solving are more transversal [27], which means they will be applied in the complicated activity composed by several simple conducts. The internal logic of DigComp can be explained as follows:

(a) Start from self-behaviour of information utilization, then proceed to the interacting behaviour of communication and collaboration and learn to integrate existing contents and create new resources.
(b) Obtain varieties of single skills through simple conduct and make full use of them to solve the particular problems in real life.
(c) Integrate safety awareness into all simple conducts and complicated activities, for constructing a secure environment to creatively solve actual problems.

In a word, skills are foundational, awareness is assurance, and competencies are synthetic representation of outstanding skills in complex circumstances.

Benefiting from the internal logic of DigComp, this paper designs DLFCS in the layout of three areas named operational skills, applied competencies and thinking & awareness. Because the acquisition of digital literacy begins with simple and solo operational skills, people need a couple of operational skills when facing the actual problems in complex circumstances. The procedure of problems solving implies the achievement of one's digital literacy from discrete operational skills to comprehensive applied competencies. Simultaneously, thinking during and after the conducts will form one's awareness (no matter how good or bad it is) that serves his/her subsequent activities. Therefore, the evolution progress of 'digital technologies utilization, actual problems solving, and digital awareness cultivation' reflected in the configuration of three areas represents the internal logic of DLFCS. Following the logic of 'Skills-Competencies-Awareness', all descriptors involved in simple conducts will be assigned to area operational skills, those required in complicated activities should be assigned to area applied competencies, the abstract awareness or attitudes are assigned to area thinking & awareness. It makes the framework structure and descriptor classification more compact and well-organized, avoiding the probable overlap and omission among descriptors and indicators.

4.2. An overview of framework

Digital literacy resides in the behaviours of digital accessing, manipulation, interaction, etc. that occur in particular digital scenes, according to the explanation in the 'Action Plan'. It is indispensable to implement thorough analysis and descriptions on the scenes relating to different digital behaviour, for the sake of framework development adapting to the situation of our nation and the characteristics of target population.

College is the last class for most people before embarking on their formal careers. College students should participate in social activities and internships to be fully prepared for employment and entrepreneurship in the intensely competitive environment. In addition, the routine affairs for college students are to learn all kinds of study methodologies and develop the habits of lifelong learning and self-motivation. After clarifying the internal logic of DLFCS, this paper will qualitatively and quantitatively interpret the digital literacy used in specific situations through scene-based requirements analysis of college students learning, working and life, and endeavor to develop a domestic framework that reflects their real vision, growing a solid foundation for the scientific evaluation of college students digital literacy. The research process is listed below:

(a) The first step is to draft an initial framework (version 1.0) structured in area operational skills, applied competencies. and thinking & awareness.
(b) The second step is to collect the scenes of college students learning, working and life in Chinese 'Double First-Class'/normal universities, art academies and vocational colleges.
(c) The third step is to map the digital literacy used in these scenes into framework 1.0 and upgrade it to version 2.0 by enriching the proficiency and examples. If not mapped, it goes back to the first step for re-generalization.
(d) The fourth step is to consult the professionals of higher education and senior administrators in enterprises on the topics of 'what digital literacy and skills are essential for college students learning, working and life', unscrambling their suggestions on the content completeness, classification rationality and scene applicability.
(e) The fifth step is to refine the descriptors and examples in framework 2.0 based on the feedback described above, and upgrade it to version 3.0 shown in Table 1.

The areas and descriptors in Table 1 are simply unraveled in brief words, additional quantified proficiency and scene examples are necessary for guiding the framework applications in actual evaluation and education. On the dimension of proficiency, DigComp 2.1 was split into eight levels according to the cognitive challenge of competencies, complexity of tasks and individual autonomy in completing the task [29]. However, such qualitative splits make it difficult to map the actual performance into each level. The first improvement of DLFCS is to designate five levels of deficient, basic, intermediate, proficient and specialized corresponding to the rating ranges of 0~19, 20~39, 40~59, 60~79 and 80~100. Whether subjective judgement or programmed rating, the range that scores fall in represent the relevant proficiency level of one's actual performance. The second improvement of DLFCS is to elaborate the scene examples of learning, working and life for 15 descriptors on five levels, listing the key features for reference of performance evaluation as shown in Table 2.

5. Evaluation of the digital literacy framework of college students

5.1. Material and methods

A stable and rational framework must stand up to continuous examination and verification. Withstanding the examination means the framework is acknowledged by most stakeholders (policymakers, educators, scholars, etc.) on the content description and logic structure. Withstanding the verification means the quantified descriptors or indicators can serve as evaluation standards to measure the actual performance of individual's and population's digital literacy. Generally, the former one is a type of

Table 1
Digital literacy framework of college students

Areas	Descriptors	Descriptions with key indicators
Operational skills	Searching & Accessing (SA)	Selecting appropriate digital tools, to **search (SAS)**, **navigate (SAN)** and **access (SAA)** the digital contents for specific needs.
	Identifying & Evaluating (IE)	To **identify (IEI)** the reliability of information sources, and to **evaluate (IEE)** the value of digital contents.
	Storing & Retrieving (SR)	To effectively **store (SRS)** and **retrieve (SRR)** the digital contents, e.g. different forms of remote backups and digital archives.
	Structured Processing (SP)	To understand how to use the digital tools of programming, images/videos editing and referencing, e.g. Python, Photoshop and EndNote. **(SP2)**
	Communicating & Sharing (CS)	Selecting appropriate digital tools, to **communicate (CSC)** and **share (CSS)** the digital contents in specific situations.
Applied competencies	Requirements Analysis (RA)	To **specify (RAS)** the objectives for specific tasks, and to **analyze (RAA)** the technical means and digital environment for achieving the objectives.
	Problems Solving (PS)	To formulate targeted solutions for particular problems, e.g. communication strategies for specific audience and storage devices for specific data. **(PS2)**
	Integrating & Creating (IC)	To integrate the present digital contents, and to create new digital resources. **(IC2)**
	Collaborating & Co-constructing (CC)	To **select (CCS)** appropriate partners, and to **co-construct (CCC)** new digital resources.
	Seek Self-development (SD)	Following the digital trends, to reasonably **plan (SDP)** one's career, and to actively get **involved (SDI)** in social services for accumulating fine reputation.
Thinking & Awareness	Morality & Etiquette (ME)	To **comply (MEC)** with cyber laws and netiquette, and to **propagate (MEP)** Chinese traditional culture.
	Safety & Security (SS)	To protect the safety and security of physical devices, digital contents and personal identities, avoiding the infringement of digital copyrights. **(SS2)**
	Health & Environment (HE)	To deal with the negative impacts of digital technologies on health and environment, e.g. scheduled web surfing and green products use. **(HE2)**
	Well-being & Inclusion (WI)	To **understand (WIU)** the digital divides, and to **propagate (WIP)** the digital environment with value pluralism, openness and inclusiveness.
	Critical Thinking (CT)	To independently think about how to use digital technologies for promoting empowerment and revolution, including when, where and extents. **(CT2)**

(a) The bold items like '**search (SAS)**' are key indicators within each descriptor. (b) The indicator identifier adopts the descriptor name plus '2', like **(SP2)**, if there is only one indicator.

Table 2
The quantified proficiency and scene examples in DLFCS

Descriptors	Proficiency	Scene examples with key performances/representations
SA	Basic ratings in 20~39	*Learning*: To search for digital contents on Baidu by keywords of 'Mogao Grottoes in Dunhuang' (in Chinese words), to view the article of 'Mogao Grottoes' on **Baidupedia**, and to watch the CCTV documentary of 'Dialogue between Mogao and Angkor', **roughly knowing** about the Mogao Grottoes overview, history and cultural relics. However, **not to gain insights** from more professional platforms, e.g. CNKI and Dunhuang Academic Resources Database, and to **be unaware** of the technological responses regarding a more user-friendly experience for specific resources.
IE	Intermediate ratings in 40~59	*Life*: To look up hotels near Xixi National Wetland Park, Hangzhou for May Day vacation, **excluding** uncertified websites and Apps against probable frauds. Based on the **price comparison**, to book two stays in the Lucid Resort from App Ctrip. However, **not to view** the feedbacks left by previous guests, and to **be unaware** of the detailed information about hotel's location, facilities, service, etc.
SR	Proficient ratings in 60~79	*Learning*: To **assign** storage location and formulate **resource catalog** for a fast and convenient retrieval in the future, when receiving and downloading the learning materials. To **scan** the important physical materials as electronic copies, and to **back up** the important data and files in local computer, portable drive and Baidu Netdisk.
SP	Specialized ratings in 80~100	*Learning*: Data analysis via **Python**: to **view** the dataset structures by plotting scatter chart and box-and-whisker diagram with the light package of Pandas, to plot radar chart (**complex diagrams** to show numerous discrete variables) with the comprehensive library of Matplotlib, and to export these diagrams to HTML documents with Bokeh library, effectuating the **interactive visual analysis**.
CS	Basic ratings in 20~39	*Working*: To communicate on **WeChat** for regular instant messaging when dialing for emergencies, and to communicate via **Emails** with accurate title, standardized format and reasonable CC in formal occasions. However, to **rarely** participate in communication and sharing within online meetings or social networking services, **not to actively create** communication channels and effectively manage communication behaviour.
RA	Intermediate ratings in 40~59	*Working*: Scope management of information system project: to **investigate** the business processes (e.g. marketing and maintenance) and application requirements on client's cite, to analyze the resourcing conditions for project completion, and to **formulate** the scope statement. However, **not to break down** the project scope from top to bottom to formulate the Work Breakdown Structure (WBS), and **not to apply** the requirement traceability matrix to prevent scope creep.
PS	Proficient ratings in 60~79	*Learning*: In order to efficiently learn the French school theory of comparative literature, to **attend** one semester intensive course of French to improve the reading ability (reaching the **DELF B1** level), and to summarize some learning tips, e.g. memorizing words and inquiring about sentence pattern and derivations on **App Frhelper**, and practising French writing on **www.cordial.fr** for familiarizing the tense and conjugation and excising the usage of grammars.

Table 2 (Continued)

Descriptors	Proficiency	Scene examples with key performances/representations
IC	Specialized ratings in 80~100	*Learning*: Based on the collected ancient books and other digital materials, to **sort out** the dancing elements in the daily, religious and political life during the Southern Song Dynasty, to create the **short videos** and **mind maps** in the ontology of knowledge elements that connect the temporal and spatial structure of the evolving dancing culture, and to construct a holistic **knowledge network** on the modality, development and esthetic of Southern Song dance.
CC	Basic ratings in 20~39	*Working*: Slow SQL troubleshooting: to **participate** in the establishment of horizontal management platforms by extracting the management experience and encapsulating the professional knowledge. However, **not** to independently organize and manage team for complicated tasks, e.g. **discovering** the efficient team members who have similar pursuit, coordinating various pursuits to **facilitate** a prioritized process, and **running** a brainstorm to activate the collective intelligence.
SD	Intermediate ratings in 40~59	*Working*: To **be aware** of the overall situation of Digital Reform in Zhejiang Province, and to fully **prepare** Alibaba's campus recruitment **hoping** to participate in the smart city construction of Hangzhou. To **participate** in the social activities, e.g. assisting elderly people to make outpatient appointment, check examination reports and consult one's illness through the service 'Healthy Hangzhou' of App Zheliban.
ME	Proficient ratings in 60~79	*Life*: To communicate online in a **courteous manner**, to **dissuade** the arbitrary forwarding of others privacy, to **boycott** the harmful acts of deliberate trolling, malicious marketing, vulgar spoof, etc., and to **report** all kinds of fake contents, illegality and crimes (e.g. publishing defamatory comments on national heroes and martyrs). To **attend** the online concert of ancient poetry and lyrics, savouring the traditional esthetic which blends the language with music.
SS	Specialized ratings in 80~100	*Learning*: To protect the laboratory facilities from the risks and threats of high temperature & humidity and power outage, to **scan** the security vulnerability of digital system and install relevant patches every week, to **update** the passwords with a combination of numbers, upper & lowercase and special characters every season, to do the antivirus scanning before clicking an unknown link or connecting a public network, **not** to transmit any **unencrypted** files or identity information in unauthorized circumstance. To **subscribe** the paid modules in the software Xmind, Origin, etc, and to **apply** the invention patent for self-developed scene recognition devices.
HE	Basic ratings in 20~39	*Life*: To **know** about the negative impacts of Internet addiction on physical and psychological health, e.g. cervical retroflexion and emotional disorder, and to reasonably **schedule** the Internet use. To know about the environmental impacts of digital technologies, e.g. electromagnetic radiation from 5G base station, and to **reduce** the replacement frequency of digital devices. However, to **rarely** persuade others to reasonably use the digital technologies.

Table 2 (Continued)

Descriptors	Proficiency	Scene examples with key performances/representations
WI	Intermediate ratings in 40~59	*Life*: To **be aware** of the fact that there exists significant difference for digital literacy proficiency among populations of different ages, regions and education backgrounds, e.g. residents in less developed regions often have poor performance on the structured processing of digital resources, to **tolerate** the underprivileged population of digital illiteracy, to **dissuade** the act of underestimating others digital literacy, and to **understand** the rationality and necessity of plural values in the digital environment.
CT	Proficient ratings in 60~79	*Learning*: To participate in the periodical assessment to **monitor** the development status of personal digital literacy, and to **attend** the particular lectures (e.g. 'Patents Searching and Information Analysis') for **improving** the identified weakness and satisfying the actual demands. To **independently think** about the usage range and level of digital technologies, i.e. the way of using digital technologies in specific situations that is more beneficial to the fundamental interests of the majority people.

(a) The bold items like '**Baidupedia**' are key performances/representations on the relevant proficiency level. (b) This table only lists one scene example per descriptor (a rolling arrangement excluding 'deficient' for proficiency column and a random selection for scene examples column), because there are at least 225 scene examples of learning, working and life for 15 descriptors on five levels that cost too many pages.

qualitatively empirical study which is relatively easy to undertake, while the latter one is a type of quantitative analysis based on the experimental feedback which is fairly arduous and time consuming. Compared to most researchers who are more concerned about the qualitatively iterative examination (similar to the second to fifth steps in the development process of DLFCS), this paper chooses to conduct a quantitative evaluation of the completeness and validity of DLFCS based on the sampling evaluation of college students digital literacy. It makes great efforts to ensure comprehensiveness, profundity and precision in all aspects of evaluation and analysis for drawing a correct and reliable conclusion.

5.2. *Sampling subjects*

Considering the region classification from National Bureau of Statistics of China and discipline characteristics and course types of each university/college, this project sampled six geographically dispersed universities/colleges (see Appendix B). It collected the self-perception of digital literacy by five-scale questionnaire in the selected universities/colleges and measured the actual performance of the same subjects by Q&A and task evaluation from late May to early July, 2022. In the questionnaire, it asked whether to participate in the upcoming Q&A tests and task evaluation or not, excluding subjects who were unwilling to complete all measurements, and asked if subjects had participated in similar evaluations of digital literacy before, minimizing the impact of subjective experience on the evaluation results. To balance the influence of disciplines and grades on the evaluation results, it referenced the real proportions from the educational statistics in 2018~2021 published by Ministry of Education of the People's Republic of China [41]. Dynamic adjustments were operated throughout the whole sampling and data cleaning procedures to ensure a minimal deviation (±3%) between the sampled proportions and the real ones. The final distribution of subjects disciplines and grades are shown in Appendix C.

5.3. Measurement instruments

The self-perception questionnaire comprises 25 single-choice questions corresponding to the 25 key indicators in DLFCS. For example, the question relating to indicator SP2 is 'Have you ever learned common programming languages (e.g. Python, Java and C++), or manipulated common digital tools of images/videos editing (e.g. Photoshop, Premiere Pro and AutoCAD) and referencing (e.g. EndNote)?' The choices are 'A. Have no knowledge on programming, and occasionally manipulate those digital tools. B. Have basic knowledge of one programming language, or usually manipulate those digital tools. C. Know well about one programming language or digital tool. D. Know well about two or more programming languages or digital tools. E. Specialize in two or more programming languages and digital tools [42]'. These options are respectively associated with the five proficiency levels (deficient, basic, intermediate, proficient and specialized), and marked the medians of each rating range, namely 10, 30, 50, 70 and 90. Eventually, 25 self-perception scores will be weighted to 15 ratings corresponding to the 15 descriptors in DLFCS, e.g. indicator SAS, SAN and SAA that belong to the same descriptor SA are equally allocated the weight coefficient 0.33.

As mentioned above, there are two ways to measure the actual performance of digital literacy, Q&A tests and task evaluation. The Q&A test is a kind of structured questionnaire in essence, which integrates the knowledge units reflecting different digital competence/awareness into the question options. As a result, it maps the 25 key indicators in DLFCS using options instead of the question itself. For example, in the question 'Please select the practices or habits that occur in your daily life? A. Set a strong sign-in password (in a combination of numbers, letters, etc.) for personal computer. B. Fill out the advertising survey with ID number or SSN for some rewards. C. Share the posts or videos that have eye-catching titles before careful reading. D. Read travel tips and plan one's itinerary on App Mafengwo [43]', the correct options A and D direct to indicator SS2 and PS2. The entire Q&A procedure incorporated 100 correct options (4 per indicator) in 50 multiple-choice questions. The grading criteria are 1 point for correct selections, 0 for incorrect ones and deduction for superfluous ones, and the same weight calculation is applied in the data processing of Q&A tests.

In the section of task evaluation, this project has designed three thematic tasks to measure the actual performance in the digital environment (see Appendix D). The first task simulates an array of working scenes on the topic of travel, mostly assessing descriptors in area applied competencies, such as descriptor RA, PS, IC and CC. The second task simulates the scene of skills training with an idea of flipped teaching, mainly evaluating descriptors in area operational skills, like descriptor SA, IE, SR and SP. Since the behaviour corresponding to descriptor SD, HE, WI and CT is very broad and difficult to quantify, the third task evaluating descriptors in area thinking & awareness demands to write an essay on the given topic and manually rated by professional graders in the range of 0~100. The grading criteria for the third task refer to the quantified proficiency and scene examples in DLFCS (see Table 2).

6. Results and discussion

In the preliminary phase, this project invited 1950 students to participate in the self-perception questionnaire (respective 500 students in Zhongnan University of Economics and Law, Lanzhou University and Southwest University of Science and Technology and respective 150 students in Capital Medical University, Zhejiang Conservatory of Music and Liaoning Agricultural Technical College). First, the 1950 samples were reduced to 1574 after excluding the participants who were unwilling to complete Q&A tests

Table 3
Correlation analysis of descriptors for the questionnaire dataset

Descriptors	SA	IE	SR	SP	CS	RA	PS	IC	CC	SD	ME	SS	HE	WI
IE	.742**													
SR	.714**	.805**												
SP	.337**	.418**	.430**											
CS	.513**	.555**	.560**	.386**										
RA	.621**	.697**	.728**	.495**	.643**									
PS	.546**	.627**	.620**	.399**	.576**	.733**								
IC	.540**	.606**	.603**	.412**	.518**	.726**	.683**							
CC	.539**	.634**	.670**	.492**	.557**	.794**	.673**	.755**						
SD	.353**	.426**	.437**	.455**	.387**	.509**	.479**	.453**	.547**					
ME	.271**	.290**	.306**	.113**	.337**	.304**	.291**	.207**	.248**	.235**				
SS	.354**	.369**	.392**	.248**	.366**	.431**	.404**	.396**	.363**	.319**	.562**			
HE	.400**	.460**	.456**	.314**	.379**	.512**	.386**	.404**	.502**	.394**	.453**	.548**		
WI	.325**	.408**	.386**	.470**	.347**	.458**	.365**	.432**	.510**	.483**	.235**	.385**	.492**	
CT	.471**	.507**	.478**	.347**	.453**	.545**	.499**	.542**	.521**	.388**	.356**	.530**	.494**	.555**

(a) ** represents statistical significance $p < 0.01$. (b) The coefficient over .800 represents extremely strong correlation, the range of .600~0.799 represents relatively strong correlation, the range of .400~0.599 represents moderate correlation, the range of .200~0.399 represents relatively weak correlation, the coefficient below .199 represents extremely weak correlation, similarly hereinafter.

and task evaluation, who had experienced similar evaluation before and who filled out the questionnaire less than two minutes or in duplicate selections and adjusting the distribution of participants disciplines and grades with the real proportions. Second, these 1574 students continued to the Q&A test and task evaluation. It obtained 1158 valid samples (including three datasets of questionnaire, Q&A tests and task evaluation) after excluding the participants who finished the Q&A test in less than 15 minutes and who had not submitted the task assignments on time or submitted incomplete ones. Third, statistical significance over 0.05 was observed under Shapiro-Wilk tests for most of 1158 valid samples, which indicated the datasets were in accord with or basically in line with normal distribution. According to the tests of internal reliability in SPSS 27.0 (see Appendix E), the three datasets from 1158 valid samples showed good parameters of internal consistency. In light of examination effectiveness and efficiency, this evaluation conducted Pearson correlation analysis for the three datasets of questionnaire (self-perception), Q&A tests and task evaluation (actual performance), exploring the correlations among 15 descriptors in DLFCS.

Table 4
Correlation analysis of descriptors for the Q&A dataset

Descriptors	SA	IE	SR	SP	CS	RA	PS	IC	CC	SD	ME	SS	HE	WI
IE	-.057													
SR	.109**	.091**												
SP	-.019	.057	.023											
CS	-.021	.317**	.082**	.029										
RA	.365**	.448**	.282**	.414**	.440**									
PS	-.093**	.504**	.294**	.294**	.287**	.208**								
IC	.470**	.569**	.350**	.271*	.510**	.300**	.286**							
CC	.294**	-.004	.284**	.411**	.261*	.156**	-.041	.005						
SD	.276**	.033	.346**	.559**	.274*	.197**	-.043	.150**	.152**					
ME	.051	.038	.051	-.016	.115**	.263*	-.135**	.281**	.259*	.376**				
SS	-.030	.178**	.083**	.019	.163**	.397**	.378**	.398**	.049	.316**	.164**			
HE	.096**	-.129**	.043	-.046	.061*	.308**	-.225**	.495**	.404**	.407**	.279**	.145**		
WI	.068*	-.196**	.014	-.062*	-.034	.290**	-.257**	-.146**	.302**	.286**	.093**	-.097**	.210**	
CT	.089**	-.168**	.036	.016	.055	.516**	-.272**	.547**	.350**	.375**	.159**	.046	.358**	.213**

(a) ** represents statistical significance $p < 0.01$, * represents statistical significance $p < 0.05$.

6.1. Correlation analysis of descriptors in DLFCS

Based on the Pearson analysis of questionnaire dataset, positive correlations are found in all pairs of 15 descriptors. The coefficients indicate that internal correlations within area operational skills, applied competencies and thinking & awareness are mostly over moderate strength as well as the correlations between area operational skills and area applied competencies, where are highlighted with borders in Table 3. The remaining correlations between area thinking & awareness and area operational skills/area applied competencies are relatively weak as shown in Table 3.

Based on the Pearson analysis of the Q&A dataset, 79 pairs of descriptors in DLFCS (75.2% of all) are significantly correlated when 86.1% of them are positive and 89.9% of them reach statistical significance at the level of $p < 0.01$. However, most of these 79 pairs are relatively or extremely weak correlations, lower than ones in the questionnaire analysis. With regard to the correlation distribution, the significant correlations between area applied competencies and area operational skills/area thinking & awareness are more agglomerate with higher coefficients (see highlighted rectangles in Table 4), while they also gather together within area thinking & awareness with relatively lower coefficients. The significant correlations are presented sparsely within area operational skills and applied competencies, between area operational skills and area thinking & awareness, as shown in Table 4.

Based on the Pearson analysis of Task Evaluation dataset, 96 pairs of descriptors in DLFCS (91.4% of all) are significantly positive correlated when 92.7% of them reach statistical significance at the level

Table 5
Correlation analysis of descriptors for the task evaluation dataset

Descriptors	SA	IE	SR	SP	CS	RA	PS	IC	CC	SD	ME	SS	HE	WI
IE	.105**													
SR	.051	.124**												
SP	.062*	.088**	.139**											
CS	.053	.161**	.146**	.206**										
RA	.334**	.339**	.359**	.516**	.424**									
PS	.280**	.350**	.366**	.521**	.520**	.508**								
IC	.337**	.319**	.307**	.467**	.369**	.485**	.510**							
CC	.369**	.285**	.302**	.439**	.314**	.293**	.236**	.302**						
SD	.356**	.298**	.267*	.384**	.313**	.313**	.335**	.312**	.239**					
ME	-.005	.089**	.134**	.182**	.199**	.427**	.500**	.395**	.320**	.276**				
SS	.010	.073*	.195**	.159**	.138**	.454**	.324**	.327**	.360**	.268*	.222**			
HE	.106**	.076*	.120**	.211**	.154**	.536**	.485**	.456**	.406**	.426**	.254**	.127**		
WI	.088**	.021	.046	.230**	.145**	.427**	.398**	.427**	.415**	.484**	.064*	.094**	.205**	
CT	-.042	.053	.148**	.170**	.134**	.402**	.344**	.339**	.306**	.052	.113**	.241**	.089**	.064*

(a) ** represents statistical significance $p < 0.01$, * represents statistical significance $p < 0.05$.

of $p < 0.01$. Most of these 96 pairs are also relatively or extremely weak correlations, lower than ones in the questionnaire analysis. With regard to the correlation distribution, the significant correlations within area applied competencies, between area applied competencies and area operational skills/area thinking & awareness are more agglomerate with higher coefficients (see highlighted rectangles in Table 5), while they also gather together within area thinking & awareness with relatively lower coefficients. The significant correlations are presented sparsely within area operational skills, between area operational skills and area thinking & awareness, as shown in Table 5.

6.2. *Discussion on the completeness and validity of DLFCS*

From the perspective of literacy areas, the internal correlations of moderate or high strength within three areas shown in Table 3 suggest that subjects acknowledge the skills/competencies/awareness coherence in their self-perception, e.g. an individual usually estimate his/her operational skills of Searching & Accessing (SA), Identifying & Evaluating (IE), Storing & Retrieving (SR), Structured Processing (SP) and Communicating & Sharing (CS) on the approximate proficiency level. In other words, proficient SA self-rating always comes with proficient IE, SR, SP and CS ones. Similarly, the correlations (mostly over moderate strength) between area operational skills and area applied competencies also suggest that subjects believe they should have decent applied competencies of Requirements Analysis (RA),

Problems Solving (PS), Integrating & Creating (IC), Collaborating & Co-constructing (CC) and Seek Self-development (SD) if confident in their operational skills. Seen from Tables 4 and 5, area applied competencies is indeed closely correlated with area operational skills/area thinking & awareness in the actual performance of subjects. The former one between area operational skills and area applied competencies implies that applied competencies are systematic application and implementation of operational skills. Only if fully mastering five kinds of operational skills and synthetically applying them into specific situations, an individual could be likely to create more digital resources and solve complicated actual problems. The latter one between area applied competencies and area thinking & awareness implies that thinking & awareness call for advanced intellectual exercises, which involve the realization after persistent information collection, abstraction, interpretation, inference, conception and correction, and the ultimate internalization of methodologies to guide more effective practices in the future. The phenomenon that coefficients in Table 3 are much higher than those in Table 4 and 5 is primarily attributed to the remarkable impact of subjective self-efficacy on the evaluation results, because individuals often overestimate their digital literacy which is validated by several scholars, like Ove Edvard Hatlevik [44], Eszter Hargittai [45], et al. Hence, the following arguments are inferred merely from the actual performance analysis (namely Tables 4 and 5):

(a) There exists at least extremely weak correlation among most pairs of descriptors in DLFCS, which not only means association but also independence.
(b) The correlations between area operational skills and area applied competencies/between area applied competencies and area thinking & awareness are remarkably stronger than those with area operational skills/area thinking & awareness, which reveals the emphases of descriptor's association between areas and descriptor's independence within areas.
(c) The correlations between area operational skills and area thinking & awareness are apparently weaker than those between area operational skills and area applied competencies/between area applied competencies and area thinking & awareness, which reveals the relationships of progressive and intertwined 'Skills-Competencies-Awareness'.

In short, there are only subtle overlaps among 15 descriptors in DLFCS, basically covering the essential areas of digital literacy (expounded from the argument a). Achieving one descriptor of digital literacy proficiently does not guarantee good performance on the other descriptors, especially for the descriptors in the same area (expounded from the descriptor's independence within areas in the argument b). The relationships of progressive and intertwined 'Skills-Competencies-Awareness' demonstrate the validity of the internal logic and DLFCS itself (expounded from the argument c), indicating that to be digital literate requires long-term and gradually-progressed cultivation and improvement (no shortcuts for quick learning). Therefore, these arguments and interpretations above sufficiently demonstrate DLFCS is a complete, valid and rational framework of digital literacy.

7. Conclusion

As the Chinese saying goes, a nation will prosper only when its young people thrive. To research and develop the DLFCS has practical significance in systematically promoting college students digital literacy and skills, expediting the construction of 'Digital China' and advancing the realization of 'Common Prosperity'. Based on the requirements analysis of learning, working and life scenes where varieties of

digital literacy are employed, this paper has developed a contextualized framework that adapts to the situation of our nation and the characteristics of target population and clarified the internal logic, three areas and 15 descriptors with explicit explanations, breaking through the limitations of indicators omission, content overlap and expression ambiguity, etc. in current digital literacy research of China. After that, a quantitative evaluation has been processed to validate the completeness and validity of framework's 15 descriptors, after sampling 1158 valid subjects by three measurements of questionnaire (self-perception), Q&A tests and task evaluation (actual performance) from six selected universities/colleges. The results indicate that 15 descriptors in DLFCS basically cover the essential areas of digital literacy that college students in the digital age should master and are capable of scientifically evaluating the individual's and population's digital literacy of college students for further precise education on one's identified weakness.

Moreover, the phenomenon that individual's self-perception always exceeds one's actual performance implies the incomprehension on the definition and descriptors of digital literacy. The youth might consider digital literacy as an approximate kind of ability to manipulate digital tools, overestimating their own digital literacy and skills. It also reveals that digital literacy, as a novel collection of complex literacies, does not originate in the constitution of one's intellect and cannot be acquired in a short time either. Students, educators, policymakers and all citizens must clearly realize that cultivation of digital literacy ought to involve inclusive instruction and training in the field of knowledge, practices and awareness which experience long term development. Certainly, there still exist a few limitations in the DLFCS evaluation, e.g. how to synchronize the descriptors and examples in DLFCS with the rapid development of digital society has not been discussed yet. More research should be attempted to study the existing or unknown limitations in the future.

Informed consent

The author has obtained informed consent from all participants.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix A

See Table A.1.

Table A.1
The digital competence framework for citizens, DigComp 2.0 [28]

Areas	Descriptors	Key indicators
1. Information and data literacy	1.1 Browsing, searching and filtering data, information and digital content	1.1.1 Articulate information needs 1.1.2 Search for data, information and digital content 1.1.3 Access and navigate between them 1.1.4 Create and update search strategies
	1.2 Evaluating data, information and digital content	1.2.1 Analyse 1.2.2 Compare 1.2.3 Critically evaluate the credibility and reliability of sources 1.2.4 Interpret data, information and digital content
	1.3 Managing data, information and digital content	1.3.1 Organise 1.3.2 Store 1.3.3 Retrieve data, information and digital content 1.3.4 Process them in a structured environment
2. Communication and collaboration	2.1 Interacting through digital technologies	2.1.1 Interact 2.1.2 Understand appropriate digital communication means
	2.2 Sharing through digital technologies	2.2.1 Share data, information and digital content 2.2.2 Know about referencing and attribution practices
	2.3 Engaging in citizenship through digital technologies	2.3.1 Participate in society 2.3.2 Seek self-empowerment and participatory citizenship
	2.4 Collaborating through digital technologies	2.4.1 Collaborate, co-construct and co-create resources and knowledge
	2.5 Netiquette	2.5.1 Be aware of behavioural norms and know-how 2.5.2 Adapt communication strategies to the specific audience 2.5.3 Be aware of cultural and generational diversity
	2.6 Managing digital identity	2.6.1 Create and manage one or multiple digital identities 2.6.2 Protect one's own reputation 2.6.3 Deal with the data relating to one's digital identities
3. Digital content creation	3.1 Developing digital content	3.1.1 Create and edit digital content 3.1.2 Express oneself through digital means
	3.2 Integrating and re-elaborating digital content	3.2.1 Modify 3.2.2 Refine 3.2.3 Improve 3.2.4 Integrate information into an existing body of knowledge
	3.3 Copyright and licences	3.3.1 Understand copyright and licences
	3.4 Programming	3.4.1 Plan and develop a sequence of understandable instructions

Table A.1 (Continued)

Areas	Descriptors	Key indicators
4. Safety	4.1 Protecting devices	4.1.1 Protect devices and digital content 4.1.2 Understand risks and threats 4.1.3 Know about safety and security measures
	4.2 Protecting personal data and privacy	4.2.1 Protect personal data and privacy 4.2.2 Understand how to use and share identifiable information 4.2.3 Understand that digital services use a "Privacy policy"
	4.3 Protecting health and well-being	4.3.1 Avoid health-risks and threats (physical and psychological) 4.3.2 Protect oneself and others from possible dangers 4.3.3 Be aware of social well-being and inclusion
	4.4 Protecting the environment	4.4.1 Be aware of the environmental impact of digital technologies
5. Problem solving	5.1 Solving technical problems	5.1.1 Identify technical problems 5.1.2 Solve them
	5.2 Identifying needs and technological responses	5.2.1 Assess needs 5.2.2 Select possible technological responses to solve them 5.2.3 Adjust and customise digital environments to personal needs
	5.3 Creatively using digital technologies	5.3.1 Create knowledge and innovate processes and products 5.3.2 Engage individually and collectively in cognitive processing
	5.4 Identifying digital competence gaps	5.4.1 Understand one's own digital competence 5.4.2 Support others with their digital competence development 5.4.3 Seek self-development and Keep up with the digital evolution

Appendix B

See Table B.1.

Table B.1
Description of sampled Universities/Colleges (Educational statistics in 2018–2021, 2021)

Universities/colleges	Regions covered	Discipline characteristics	Course types
Capital Medical University	North China	Medicine and Pharmacy	Normal
Zhejiang Conservatory of Music	East China	Art	Art
Liaoning Agricultural Technical College	Northeastern China	Agriculture and Forestry	Vocational
Zhongnan University of Economics and Law	Central China	Finance, Economics, Political Science and Law	'Double First-Class'
Lanzhou University	Northwestern China	Comprehensive University	'Double First-Class'
Southwest University of Science and Technology	Southwestern China	Polytechnic	Normal

(a) 'Double First-Class' Universities are the top 147 institutions that educate the most outstanding academic and professional graduates in China.

Appendix C

See Table C.1.

Table C.1
Distribution of subjects' disciplines and grades

Disciplines	Number of subjects	Sampled proportions	Real proportions	Grades	Number of subjects	Sampled proportions	Real proportions
Philosophy, Law, History, etc.	222	19.2%	18.2%	Undergraduate freshman	301	26.0%	27.5%
Economics and Management	230	19.9%	21.3%	Undergraduate sophomore	283	24.4%	26.6%
Science	107	9.2%	7.0%	Undergraduate junior	264	22.8%	25.2%
Engineering	365	31.5%	34.3%	Undergraduate senior	129	11.1%	11.6%
Agriculture	53	4.6%	2.1%	Master of 1st year	65	5.6%	2.9%
Medicine	93	8.0%	8.3%	Master of 2nd year	48	4.1%	2.7%
Art	88	7.6%	8.8%	Master of 3rd year	40	3.5%	2.2%
Total	1158	100%	/	Ph.D.	28	2.4%	1.2%

Appendix D

See Table D.1.

Table D.1
Brief description of task evaluation design

Order	Scene emphases	Task contents	Assignments	Descriptors evaluated
1st	Life concerned, working involved	1.1 Acting as the product manager in a travel agency, to process inquiries from three AI clients and customize personalized travel plan for them, including transportation, dining, accommodation, entertainment, etc. 1.2 To design a travel product suitable for the same demographic, and to run a digital advertising campaign collaborating with one or two partners, e.g. live streaming on App TikTok.	Travel plan submitted in two credit hours, Travel product submitted in two days, Advertising campaign ran in two weeks.	SP, CS, RA, PS, IC, CC and ME
2nd	Learning concerned, working involved	2.1 To create an one-hour online course about investment and financing, e.g. how to interpret the equity volatility on the basis of probability distribution, and to establish the investment portfolio using generalized correlations.	Online course submitted in three days, Virtual account assessed in one month.	SA, IE, SR, SP, PS, IC and SS

Table D.1 (Continued)

Order	Scene emphases	Task contents	Assignments	Descriptors evaluated
		2.2 To execute a short term security trading in a virtual account of network platform, exploiting the knowledge and skills instructed in the online course, e.g. 'fast in, fast out' for the hot quotations.		
3rd	Values concerned, learning, working and life all involved	3.1 To write an open essay on the value creation and potential crisis of digital intelligence, talking about one's career vision and life plan.	Essay submitted in one week.	SD, HE, WI and CT

(a) Cronbach's Alpha over 0.8 generally means the dataset has high level of internal consistency.

Appendix E

See Table E.1.

Table E.1
Reliability statistics of three datasets

Datasets	Questionnaire	Q&A	Task evaluation
Cronbach's Alpha	.928	.812	.825

(a) Cronbach's Alpha over 0.8 generally means the dataset has high level of internal consistency.

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