Determining Digital Literacy Competencies in Technical Senior High Schools Using Fuzzy Delphi Analysis

David W. S. Tai, Ren-Cheng Zhang, Yu-Te Wang, and Ray Wang

***Abstract*—The main purpose of this study was to establish appropriate competency indicators for Digital literacy of technical senior high schools in Taiwan. The paper describes and discusses the final results by using the expert panel and Fuzzy Delphi method, involving 32 experts from academia, school teacher and industrial information related areas. Furthermore, the Fuzzy Delphi technique was conducted and 53 competency indicators were proposed after this process. In the finding of the Fuzzy Delphi analysis, the experts thought that the most important competencies are "Recognize the legal consequences of plagiarism and the need for personal authenticity in their work", "Respects intellectual property rights", and "Recognize that using media or technology to defame, libel, or misrepresent another person or group constitutes unacceptable behavior".**

***Index Terms*—Digital literacy, expert panel, fuzzy Delphi.**

I. Introduction

Gilster [1] first used the term "digital literacy" in the context of a wider reflection on the potentials of the Internet and defined it as 「the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers' (p. 1)」. Digital literacy or as it is termed by some, digital literacies have received a great deal of attention in the recent years with much wrangling over definitions and the extent of this term [2]. Subsequently, a broader concept appeared, transcending technical ICT skills and including skills linked to the capacity to solve information and communication problems in a digital environment. For example, searching, assessing, summarizing, analyzing, representing, or creating information; as well as sharing and collaborating with others [3]. Leading professional organizations have called for increased integration of digital literacy into the school curriculum, including the ability to find and evaluate information on the Internet [4]. So far, little research has been focused on student performance in a digital context, partly due to the difficulty of defining and measuring ICT or digital skills [3]. Middle school is a logical focal point for increasing integration of digital literacy into the curriculum [4]. Updating these abilities will be necessary, as people's circumstances change and as changes in the digital information environment bring about the need for new understandings and abilities [5]. Therefore, this study suggests that digital literacy competencies need for more in-depth discussion and research.

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II. Literature Review

A. Digital Literacy

As central topics in the information sciences and 21st century education, information literacy and digital literacy have been discussed in research studies with varied terminologies and meanings [6]. Digital literacy is a broader concept than ICT literacy. In general, digital literacy frameworks may be reflected in the use of digital technology, communication tools and networks to access, manage, integrate, evaluate and create information in order to function in the information society [7]. It also includes elements of information literacy, media literacy, and visual literacy [8]. Digital literacy refers to the knowledge and skills that all persons need for professional development and for active participation in a technological-based society [9]. Digital literacy skills also including experiences with and management of e-safety and risk [10]. Digital literacy is a broader concept that integrates several skill-sets and related literacies, such as information evaluation and knowledge gathering [11]. Digital literacy also includes skills in critical information retrieval, data processing and the ability to take advantage of the diversity of digital media [12]. In recent years, studies of digital literacy accentuate the need of getting beyond the basic skills of using the information and digital literacy tools and resources and developing strategies for a critical and efficient use of these means [13].

JISC definition used in this study will be divided into following digital literacy: 1. Media literacy: Critically read and creatively produce academic and professional communications in a range of media; 2. Information literacy: Find, interpret evaluate, manage and share information; 3. ICT literacy: Adopt, adapt and use digital devices, applications and services; 4. Learning skills: Study and learn effectively in technology-rich environments, formal and informal; 5. Communications & collaboration: Participate in digital networks for learning and research; 6. Career & identity management: Manage digital reputation and online identity [14].

III. Methodology

A. Fuzzy Delphi

Fuzzy Delphi Method (FDM) was derived to solve the problem of traditional Delphi method [15]. This method bases on group thinking of the qualified experts that assures the validity of the collected information [16]. The operational stages of the modified fuzzy Delphi method are as follows [17].

Stage 1: Collect the fuzzy interval values of relevance scores. This study collected the interval values of the relevance scores assigned by experts to each evaluation criterion. The minimum interval value (most conservative cognitive value) is indicated by C, while the maximum value (most optimistic cognitive value) is indicated by O; a is the optimal representative value as determined by experts (subjective cognitive value). C^i , O^i and a^i respectively represent the minimum value, maximum value, and subjective cognitive value of the relevance score for evaluation criterion i.

Stage 2: Eliminate extreme values. This study calculated the mean and standard deviation of the minimum value, maximum value, and subjective cognitive value of evaluation criterion i. Extreme values that fell beyond the range of mean ±2 standard deviation were eliminated.

Stage 3: Determine the triangular fuzzy number for the relevance scores of assessment factors.

Stage 4: Test for consistency. The gray zone test was used to test for consistency among the opinions of experts (test value $Z^i = (O^i_M - C^i_M) - (C^i_U - O^i_L)$). When $C^i_U > O^i_L$ and $Z^i \geqq 0$, this indicates expert opinions are converging (consistent).

Stage 5: Calculate the value of consensus among experts. In Figure 1, the cognitive value corresponding to the intersection point of C^i and O^i is the value of consensus among experts (indicated by G^i) in relation to the relevance score of evaluation criterion i. The higher the value of G is, the higher the consensus among experts of the significance of this assessment factor.

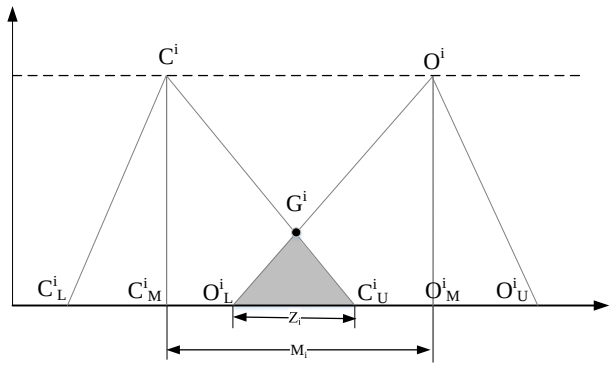

Fig. 1. Two triangular fuzzy numbers.

B. Participants

The study used the expert panel, Fuzzy Delphi method approach to conduct the basis competencies of Digital literacy, and the main goal of using the Fuzzy Delphi method was to collect and conclude the opinions from 32 industrial, school teacher and the academic experts in the information related areas. The first phase of data collection involved semi-structured interview with 32 experts in digital literacy based in the different field. The digital literacy identified form the researcher were used for develop the " Digital literacy Fuzzy Delphi Survey".

Second phase, the "Digital literacy Fuzzy Delphi Survey" is to get the agreement based on the themes given by the experts. The consensus survey will be using the Fuzzy linguistic scale anchored in strongly disagree and strongly agree. Experts will be required to indicate the extent of their agreement with the statements given. It will be constructed based on the experts raised from the conducted interview in the previous phase. For this purpose about 32 experts in Digital literacy involved and responses the survey.

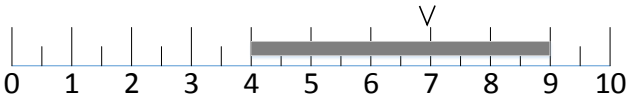

Fig. 2. Fuzzy linguistic scale.

Fuzzy Delphi technique were conducted and 53 competency indicators were proposed after this process. In addition, it should be at least five to ten per category from different professional groupings [14]. Overall, there were 32 participants in the whole process, and the effective response rate was 100%, and there were 9 participants from the academia, 15 participants from the school and 8 from the industry as shown in Table I. Therefore, it fitted in with the assumption.

TABLE I: DELPHI GROUPINGS AND NUMBER OF PARTICIPANTS

Type	No.	Percentage
Academia	9	28%
School teacher	15	47%
Industry	8	25%
Sum	32	100%

IV. RESULTS

Based on the literature review and expert panel, the dimension of digital literacy are Media literacy, Information literacy, ICT literacy, learning skills, communications & collaboration, and career & identity management. According to the survey of the Fuzzy Delphi, the total number of competency indicators is 53. The number of each individual dimension is shown in Table II. Overall the indicator G^i are over mean 7.088, and it means the experts agreed the indicators are fairly important (see Table III-VIII).

TABLE II: NUMBER OF DIMENSIONS AND INDICATORS

Dimensions	Number of indicators
Media literacy	4
Information literacy	10
ICT literacy	4
Learning skills	7
Communications & collaboration	6
Career & identity management	22
Sum	53

TABLE III: RESULTS OF FUZZY DELPHI IN MEDIA LITERACY

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T11	Identify common graphic, video, and sound file formats (e.g., JPEG, GIF, MPEG, QUICKTIME, and WAV).	8	7	1	3.420	7.335

T12	Enjoy reading or listening for pleasure.	7	7	0	3.034	7.150
T13	Express personal reading or listening experience.	8	7	1	3.345	7.167
T14	Use draw, paint, graphics, or presentation software to visually communicate ideas or concepts.	8.5	6.5	2	3.209	7.195

TABLE IV: RESULTS OF FUZZY DELPHI IN INFORMATION LITERACY

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T21	Use advanced search tools and techniques or simulations and digital models to locate or generate precise data and information that supports the development of new understandings.	8	7	1	3.406	7.160
T22	Select and use a range of ICT independently and collaboratively, analyses information to frame questions and plan search strategies or data generation.	8	7	1	3.139	7.265
T23	Search, read, log, and note take information from a variety of sources (e.g., online encyclopedias, databases, eBooks available on the school library website, the Internet).	8	8	0	3.255	7.604
T24	Independently develop keywords and phrases to search for information.	8	3	0	3.357	7.751
T25	Use Boolean operators with human or programmed guidance to narrow or broaden searches.	8	7	1	3.416	7.345
T26	Can review the information search process, and revise the keyword if necessary.	8	5	3	3.524	7.188
T27	Manipulate graphics objects in a word processing program	8	7	1	3.238	7.408
T28	Organizes information for practical application.	8	7	1	2.799	7.252
T29	Can integrate information technology to communicate effectively express.	8	7	1	3.306	7.208
T210	Identifies inaccurate and misleading information.	8	5	3	3.138	7.228

TABLE V: RESULTS OF FUZZY DELPHI IN ICT LITERACY

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T31	Familiar with the use of ICT systems and simple troubleshooting.	8	5	3	3.195	7.214
T32	Search for and access to Internet resources and use its resources or services.	8	6	2	3.329	7.429
T33	Using ICT to address the daily life and learning problems.	8	7	1	3.4	7.387
T34	Manage and maintain data securely in a variety of storage mediums and formats.	8	6	2	3.158	7.385

TABLE VI: RESULTS OF FUZZY DELPHI IN LEARNING SKILLS

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T41	Understanding Self-learning ability how to influence lifelong learning.	8	7.5	0.5	3.617	7.317
T42	Establish personal goals in pursuit of individual interests, academic requirements, and career paths.	7	7	0	3.289	7.165
T43	Work independently and take responsibility for their study progress.	7	7	0	3.228	7.221
T44	Use eLearning to support and extend learning	8	7	1	2.999	7.273
T45	Use digital tools for a curricular purpose (e.g., digital camera, voice recorder, interactive technologies, digital probes/sensors, hand-held devices, GPS – Global Position Systems).	8.5	6	2.5	3.252	7.468
T46	Applies information in critical thinking and problem solving.	8	6	2	3.133	7.090
T47	Understand the importance of creativity, innovation, and invention.	8	5.5	2.5	3.523	7.128

TABLE VII: RESULTS OF FUZZY DELPHI IN COMMUNICATIONS & COLLABORATION

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T51	Shares knowledge and information with others.	8	8	0	3.286	7.416
T52	Involves not only communication with technology, but also consideration of audience.	8	6	2	3.051	7.246
T53	Create, lead, participate, and collaborate in an online environment to support and extend learning (e.g., email, online forums, RSS feeds, virtual worlds, video web conferences).	8	5.5	2.5	3.169	7.197
T54	Respects others' ideas and backgrounds and acknowledges their contributions.	8	8	0	3.252	7.770
T55	Specify and detail workgroup goals and individual and subgroup responsibilities finalize workgroup strategies, resources, budget, and timeline.	8	6	2	3.185	7.237
T56	Can choose the appropriate information technology in cooperation with others for complete the work.	8	6	2	3.29	7.126

TABLE VIII: RESULTS OF FUZZY DELPHI IN CAREER & IDENTITY MANAGEMENT

Serial no	*Indicator*	C^i_U	O^i_L	Z^i	M^i	G^i
T61	Exploration of Information Technology with interest.	8	6	2	3.216	7.271
T62	Can be willing to explore emerging information technology.	8	7	1	3.329	7.118
T63	Understand approach and career development in IT-related industry.	7	7	0	2.903	7.358
T64	Respects the principle of equitable access to information.	8	7	1	3.133	7.366
T65	Respects intellectual property rights.	8	8	0	3.1	8.165

TABLE VIII: RESULTS OF FUZZY DELPHI IN CAREER & IDENTITY MANAGEMENT CONTD

Serial no	Indicator	C^i_U	O^i_L	Z^i	M^i	G^i
T66	Able to cite all literature sources correctly.	8	6.5	1.5	3.222	7.579
T67	Explain why "fair use" is permitted for educational purposes but not in "for profit" situations.	8	5	3	3.307	7.227
T68	Legally obtains, stores, and disseminates text, data, images, or sounds.	8	6	2	3.01	7.877
T69	Distinguish among freeware, shareware, and commercial software.	8	8	0	2.88	7.920
T610	Recognize the legal consequences of plagiarism and the need for personal authenticity in their work.	9	8	2	2.759	8.296
T611	Demonstrate an understanding of	8	5.5	2.5	3.085	7.270

	the process for copyrighting/protecting their own original work.					
T612	Understand the responsibility for use of Information Technology.	8.5	6.5	2	2.927	7.537
T613	Recognize the need for privacy of certain data files or documents	8	7.5	0.5	3.044	7.634
T614	Understand the IT-related legal, ethical and social issues, to protect themselves and respect others.	8	7	1	2.709	7.591
T615	Recognize that using media or technology to defame, libel, or misrepresent another person or group constitutes unacceptable behavior.	9	7	2	2.828	8.011
T616	Use technology efficiently and in a manner that does not harm them or others.	9	7	2	2.847	7.799
T617	Able to adopt healthy usage and attitude when using ICT.	8.5	6.5	2	2.94	7.697
T618	Able to practice healthy lifestyle of citizen in digital society.	8	7	1	2.775	7.568
T619	Understand and demonstrate safe, respectful, and responsible online communication (e.g., email, online forums, social networks, ecommerce).	9	8	1	3.071	7.894
T620	Independently apply appropriate strategies to protect rights, identity, privacy and emotional safety of others when using ICT.	8	8	3	3.106	7.122
T621	Use a range of strategies for securing and protecting information, assess the risks associated with online environments and establish appropriate security strategies and codes of conduct.	8	6	2	3.025	7.348
T622	Manage and maintain data securely in a variety of storage mediums and formats.	8	6	2	3.066	7.372

V. Conclusion

This study used the expert panel and the Fuzzy Delphi method to clarify the viewpoints of Digital literacy competencies from the academia, school teacher and the industry experts. In the finding of the Fuzzy Delphi analysis, the experts thought that the most important competencies are "Recognize the legal consequences of plagiarism and the need for personal authenticity in their work", "Respects intellectual property rights", and "Recognize that using media or technology to defame, libel, or misrepresent another person or group constitutes unacceptable behaviour", from Career & Identity Management. Next, "Distinguish among freeware, shareware, and commercial software", "Understand and demonstrate safe, respectful, and responsible online communication (e.g., email, online forums, social networks, ecommerce)" and "Legally obtains, stores, and disseminates text, data, images, or sounds" are important as well.

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References

[1] P. Gilster, *Digital Literacy*, Wiley Computer Pub., 1997.
[2] E. Tan, "Informal learning on YouTube: exploring digital literacy in independent online learning," *Learning Media and Technology*, vol. 38, pp. 463-477, Dec. 1, 2013.
[3] M. Claro, T. Cabello, E. San Martin, and M. Nussbaum, "Comparing marginal effects of Chilean students' economic, social and cultural status on digital versus reading and mathematics performance," *Computers & Education*, vol. 82, pp. 1-10, Mar. 2015.
[4] J. Colwell, S. Hunt-Barron, and D. Reinking, "Obstacles to developing digital literacy on the internet in middle school science instruction," *Journal of Literacy Research*, vol. 45, pp. 295-324, Sep. 2013.
[5] L. L. Martins and F. W. Kellermanns, "A model of business school students' acceptance of a web-based course management system," *Academy of Management Learning & Education*, vol. 3, pp. 7-26, Mar. 2004.
[6] W. W. F. Lau and A. H. K. Yuen, "Developing and validating of a perceived ICT literacy scale for junior secondary school students: Pedagogical and educational contributions," *Computers & Education*, vol. 78, pp. 1-9, Sep. 2014.
[7] S. Javorsky and R. Horvath, "Phenomenon of digital literacy in scope of European cross-curricular comparison," in *Proc. 3rd Cyprus International Conference on Educational Research (Cy-Icer 2014)*, vol. 143, pp. 769-777, 2014.
[8] A. Martin, "DigEuLit — A European framework for digital literacy: A progress report," *Journal of eLiteracy*, vol. 2, pp. 130-136, 2005.
[9] H. Uzunboylu, "A review of two mainline E-learning projects in the European Union," *Etr&D-Educational Technology Research and Development*, vol. 54, pp. 201-209, Apr 2006.
[10] S. Cranmer, "Listening to excluded young people's experiences of e-safety and risk," *Learning Media and Technology*, vol. 38, pp. 72-85, Mar 1 2013.
[11] S. Mohammadyari and H. Singh, "Understanding the effect of e-learning on individual performance: The role of digital literacy," *Computers & Education*, vol. 82, pp. 11-25, Mar 2015.
[12] M. Thorell, P. K. Fridorff-Jens, P. Lassen, T. Lange, and L. Kayser, "Transforming students into digital academics: A challenge at both the individual and the institutional level," *BMC Med Educ*, vol. 15, p. 48, Mar 14 2015.
[13] T. Shopova, *Integration of ICTS in Education and Raising the Digital Literacy of Students in the University Environment*, 2014.
[14] JISC. (2015). *Digital Literacy Framework*. [Online]. Available: https://www.jisc.ac.uk/guides/developing-digital-literacies
[15] A. Ishikawa, M. Amagasa, T. Shiga, G. Tomizawa, R. Tatsuta, and H. Mieno, "The max-min Delphi method and fuzzy Delphi method via fuzzy integration," *Fuzzy Sets and Systems*, vol. 55, pp. 241-253, May 10 1993.
[16] S. N. A. Mohamad, M. A. Embi, and N. Nordin, "Determining e-portfolio elements in learning process using fuzzy Delphi analysis," *International Education Studies*, vol. 8, p. 171, 2015.
[17] J.-H. Lin and C.-J. Yang, "Applying analytic network process to the selection of construction projects," *Open Journal of Social Sciences*, vol. 4, p. 41, 2016.

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