THE RIGMA MODEL AS A VALUABLE TOOL FOR EVALUATING TEACHERS' TECHNOLOGICAL ADVANCEMENT IN DISTANCE EDUCATION

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Abstract: The study aims to develop a model for evaluating the technological advancement of teachers engaged in distance education, with variations explained by their individual attributes. These attributes encompass organization skills, adaptation, communication abilities, independence, proficiency, efficiency, and attitude towards distance education. The study involved surveys conducted on 130 geography teachers in Poland during the initial months of the pandemic. The authors hypothesized that the variability in technological advancement could be attributed to the functional capabilities of maps used in geography lessons and the identified personal characteristics. To test these assumptions, 25 original indicators were devised, forming the Technological Advancement Index (TAI). Through statistical analysis, a disparate technological advancement among teachers was observed, with TAI scores ranging from +6.0 to −10.60. At the lower proficiency levels, variability was primarily linked to independence, followed by proficiency and efficiency. As advancement levels increased, so did the functional diversity of maps used, particularly in problem-solving and the creation of new digital maps. This exploration into technological advancement yielded novel conceptual and empirical insights, allowing validation of the Substitution, Augmentation, Modification, Redefinition (SAMR) model used in traditional education. Additionally, it led to development of the Recommendation, Imitation, Gamification, Mobilization, Action (RIGMA) model tailored for distance education. The proposed model holds applicability in enhancing geographic education during distance learning initiatives.

Keywords: RIGMA model, geographic education, distance education, technological advancement, teachers, maps

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Introduction

In March 2020, the initial phase of the pandemic commenced, defined by Chase and Taylor-Guy (2020) as an immediate response to preserve the continuity of learning. The 2020 UNESCO (2020a, b) report emphasized the lack of support for teachers worldwide, a sentiment echoed by a survey of Polish teachers. According to Buchner et al. (2020), 10% of Polish teachers lacked proper equipment, 46% found it challenging, and half faced issues with adequate Internet connections. The issue of 'digital exclusion' extended beyond Poland, affecting countries like the UK and the US (Herold 2020, McCabe 2020, Greenhow et al. 2021). Consequently, the seamless integration of technology faced challenges globally, leading to difficulties in implementing various forms of distance education.

Distance education (Taylor 1995), also called distance learning (Bokayev et al. 2021) or online

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education (Parmigiani et al. 2021), plays a pivotal role in community development. Learning through Internet resources facilitates global education (Nsiah 2011). Distance education at higher levels, although initially used marginally, gained acceptance as a generally approved alternative to traditional direct education (McIsaac, Gunawardena 1966). Distance education was rarely utilized in the geography departments in Poland before the pandemic. E-learning was limited to occasional classes, and there was a notable absence of distance education at the lower educational levels. In 2015, free online resources in the form of e-books were made available to teachers, which gave rise to research on the use of technology in education (e.g., Hibszer, Szkurłat 2015, Polak 2015).

As corroborated by studies conducted in Poland, a few years before the pandemic technological acceptance among Polish geography teachers did not translate into adequate technological preparedness (Stefaniak 2013, Plebańska et al. 2017, Żyto, Cichoń 2019). A clear illustration of the limited technological advancement among geography teachers often manifests in their insufficient skills to utilize geographic information system (GIS) tools, such as creating digital maps (Głowacz 2015). This skill deficiency becomes particularly noteworthy given that the incorporation of GIS tools is compulsory in the geography core curriculum (Szkurłat et al. 2018), presenting a significant challenge for educators (Piotrowska 2018).

The aim of this study is to construct a Recommendation, Imitation, Gamification, Mobilization, Action (RIGMA) model for assessing the technological advancement of teachers engaged in distance education, taking into account their individual characteristics.

The first hypothesis accepted was that the level of advancement of geography teachers is determined by commitment (Lee et al. 2018) and communication accessibility (Inman et al. 1999). In this study, distance education is defined as a mode of teaching and learning that transcends constraints of time and space (Webster, Hackley 1997, Piotrowska et al. 2022), assuming a basic proficiency in computer, Internet, and online application skills. Considering the mandatory use of geo-information technologies like GIS for crafting digital maps, teachers' interactions with maps of diverse functionalities serve as the yardstick for evaluating technological advancement.

Therefore, the second hypothesis accepted was that the functional capabilities of utilizing maps increase with advancement. Maps find

Table 1. Theoretical assumptions for the RIGMA model of teachers' technological advancement, as a modification of the SAMR model distinguishing into four levels of technology integration with consideration of map functionality.

Substitution	At this stage, teachers and students employ text programs instead of traditional paper methods (Islam 2018). Technology is not imperative for the mapping task, given the prevalent administering approach. In this context, the student assumes a passive role as a recipient of knowledge, whereas the teacher functions as a lecturer. Consequently, the map serves merely as a tool for visualizing phenomena and processes.
Augmentation	The primary goal of technology is to augment the learning experience (Danieluk 2019). At this level, teachers utilize maps, among other tools, to enhance the illustration and assimilation of discussed content by students. The Nearpod application proves valuable not just for map presentations but particularly for the analysis of maps, marking objects, and drawing conclusions.
Modification	This represents a phase of purposeful technology utilization for creatively executing tasks and showcasing outcomes, as students transition from passive knowledge recipients (Dylak 2013). At this stage, the map evolves into a fundamental tool for problem-solving. An intriguing application of map functionality includes an online geographic atlas (http://www.maplab.pl) or leveraging the geoportal resource www.geoportal.gov.pl, which facilitates access to spatial data and associated services.
Redefinition	This phase exclusively depends on the utilization of GIS tools and applications. The foundation for creativity, as suggested by Islam (2018), encompasses old maps, archival and satellite images, along with the geoportal. During this stage, students share the information they have gathered, and leveraging technological knowledge, including the QGIS program, they can collaboratively generate a multi-layered map.

extensive applications in various fields such as art, business, and advertising and the widespread availability of map-making software has made it relatively accessible for individuals to craft professional-looking maps (Wiegand 2006). The surge in online services offering access to maps or digital atlases through GISs underscores the heightened significance of map science today (Wiegand 2006). Eugeniusz Romer, the innovator behind the contour color scale on hypsometric maps, asserted that *only an atlas can be the foundation of the science of geography* (Piskorz 1997, as cited in Stefaniak 2013, p. 103). The escalating importance of digital maps, overshadowing traditional paper/analog maps, is supported by a study on field navigation conducted at Liverpool Hope University between 2010 and 2012 (Axon et al. 2012, Speake, Axon 2012). A majority of respondents (18- to 20-year-olds) perceived paper maps as impractical, attributing their reluctance to use them to a lack of competence (ibid.). This mindset aligns with the perspective of digitally proficient young individuals, often termed digital natives, who perceive the world through a technological lens (Dylak 2013). However, the incorporation of geo-information technologies alone does not guarantee the establishment of an active learning environment (Słomska-Przech, Pokojski 2019, Piotrowska et al. 2023); what is essential is the ability to create and utilize digital maps as a foundation for analyzing and deducing cause-and-effect relationships in the environment.

The principal method for imparting spatial analysis and inference skills involves working with maps, underscoring the importance for geography teachers to employ geo-information technology in searching, analyzing, and visualizing. The map as the primary source of geographic information is indicated in the core curriculum (Szkurłat et al. 2018, Piotrowska, Abramowicz 2021) as the most important and obligatory teaching resource in the work of a geography teacher. Since the distribution of objects and processes has a spatial dimension, there is a legitimate need for various GIS tools.

There is a lack of research in the literature on teachers' use of maps in a distance environment. It has been observed that the process of developing map reading skills using digital tools is not only difficult to implement, but also difficult to research. This process includes not only substantive content, but also pedagogical issues taking place in a distance environment using technology. The importance of these key components is highlighted in the TPACK model (Mishra, Koehler 2006). The study assumes that the fourth element of this process is teachers' technological skills. The substitution, augmentation, modification, redefinition (SAMR) model (Puentedura 2013), used in a study by Wijaya et al. (2021), may be helpful in understanding the variability of teachers' level of technological advancement. Due to the need to determine the level of technological advancement of teachers during distance education, an attempt was made to create the RIGMA model (Table 1).

Methodology

Survey study

Between April and June 2020, a survey was carried out targeting geography teachers in primary and secondary schools across Poland. The survey questionnaire was disseminated through social media, reaching approximately 4000 teachers. Respondents provided electronic responses using the Google Forms application. The questionnaire was structured into thematic sections covering programs and tools used, multimedia utilization, and an evaluation of distance education within geography education.

The survey methodology incorporated quantitative and qualitative aspects, utilizing closed and open-ended questions. This approach allowed teachers to offer a more personalized assessment of their teaching situations, encompassing communication, teaching methodologies, and evaluation systems. Prior to the main survey, a pilot study was conducted following established methodologies (Babbie 2009, Łobocki 2010).

In terms of sample distribution, the quantitative survey involved 130 geography teachers from Poland, with >50% indicating employment in elementary schools and one in three in secondary schools. Regarding gender representation, 84.6% of respondents were women. The majority of participants had an average tenure exceeding 15 years (69%), whereas the remainder reported shorter tenures.

Creation of original indicators for evaluating the technological advancement of teachers

To assess the technological advancement of geography teachers in distance education, seven personal characteristics of teachers were utilized, from which 25 original indicators were derived: Organization (WO1, WO2, WO3, WO4), Adaptation (WA1), Communication (WC1, WC2), Independence (WI1, WI2, WI3, WI4, WI5, WI6), Proficiency (WP1, WP2, WP3, WP4, WP5, WP6), Efficiency (WE1, WE2, WE3, WE4), and Attitude toward distance education (WT1, WT2).

The original indicators employed in the teacher technology advancement model (Table 2) were formulated based on the following questionnaire questions:

No. 1. Kindly provide a list of the tools or services you utilize for organizing distance education activities, such as contacting students, parents/guardians, fellow teachers, checking attendance, submitting assignments, entering grades, etc.

Table 2. 25 original indicators of technological advancement with the corresponding questionnaire items.

No.	Indicator	Questionnaire items
1	WP3	1.; 3.; 22.
2	WT1	10.
3	WT2	16. 16.
4	WC2	26.
5	WE2	10.; 26.
6	WO1	6_ 1.
7	WI1	4_4.; 4_6.
8	WP1	3.; 22.
9	WP5	3.; 4_4.; 4_6.; 22.
10	WI6	4_1.; 4_2.; 4_4.; 4_5.; 4_6.; 4_9.
11	WE1	4_1.; 4_2.; 4_4.; 4_5.; 4_6.; 4_9.; 6_1.
12	WI4	3.; 4_4.; 4_6.; 6_1.; 7_6.
13	WI3	4_4., 4_6., 6_1.,
14	WO4	3.; 7_6.
15	WI5	4_1.; 4_2.; 4_4.; 4_5.; 4_6.; 4_9.
16	WC1	1., 6_1.; 7_8.
17	WA1	18.
18	WI2	4_1.; 4_2.; 4_5.; 4_9.
19	WP4	4_1.; 4_2.; 4_5.; 4_9.; 7_2.; 7_9.
20	WP2	1.; 3.; 22.
21	WO2	7_6.
22	WO3	6_1.; 7_6.
23	WP6	3.; 6_1.; 7_6.; 22.
24	WE4	3.; 10.; 16.; 22.
25	WE3	3.; 7_9.; 18.

No. 3. Please specify the names of the programs or tools you employ to independently prepare multimedia materials for your students (e.g., MS Word, PowerPoint, Inkscape, Photoshop, Canva, Movie Maker, etc.).

No. 4. Indicate the frequency with which you utilize multimedia obtained from Internet resources in your remote geography teaching. Breakdown by categories: 4_1. [teaching games, quizzes]; 4_2. [videos/animations on geography]; 4_4. [shared multimedia presentations]; 4_5. [online maps, geoportals]; 4_6. [websites with developed materials, educational portals]; 4_9. [tutorials].

No. 6_1. Estimate the average number of hours per week you spent during traditional education (pre-epidemic) teaching lessons at school.

No. 7. Estimate the average number of hours per week you currently spend during distance education on various activities: 7_2. [preparing worksheets and text materials]; 7_6. [preparation of interactive exercises, quizzes, and tests]; 7_8. [communication with students and parents]; 7_9. [training].

No. 10. Assess to what extent it is feasible to develop the listed skills among students through distance education [%].

No. 16. Provide your opinion on whether you believe distance education is as effective as a traditional geography lesson conducted in the classroom.

No. 18. Specify the duration it took you to adapt to the new form of education.

No. 22. Indicate whether you have acquired proficiency in using entirely new tools or programs during distance education. If so, please specify.

No. 26. Evaluate which communication model (correspondence, tele-educational, multimedia, virtual) you believe is most conducive to geographic education.

Statistical analyses

Statistical analyses were conducted using two software packages: IBM Corp. (2020). IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp The jamovi project (2024). *jamovi* (Version 2.5) [Windows 11]. Australia: Sydney. Retrieved from https://www.jamovi.org

In the initial phase of the analyses, a descriptive statistical examination was performed on the analyzed variables, encompassing measures of position, spread, variability, and asymmetry. The selection of technological advancement indicators was guided by these measures.

Subsequently, data reduction was implemented using the inverse correlation matrix method (Malina, Zeliaś 1997). The selection of appropriate indicators aimed to incorporate variables providing complementary information while maintaining minimal correlation among themselves. Simultaneously, these variables should exhibit a strong connection with the analyzed level of technological advancement. This method, utilizing the multiple correlation coefficient (Zeliaś et al. 2002), surpasses classical Pearson's linear correlation analysis by offering enhanced properties. It provides information on the strength of the relationship between the j-th indicator ($j = 1, \ldots, m$) and all other indicators ($p = 1, \ldots, m$), where p is not equal to j. The first step involves determining the inverse correlation matrix [1].

$$\mathrm{R}^{-1} = \begin{bmatrix} 1 & \bar{r}_{12} & \ldots & \bar{r}_{1m} \\ \bar{r}_{21} & \bar{r}_{22} & \ldots & \bar{r}_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ \bar{r}_{m1} & \bar{r}_{m2} & \ldots & \bar{r}_{mm} \end{bmatrix},$$

$$\text{for } \mathrm{R} = \begin{bmatrix} 1 & r_{12} & \ldots & r_{1m} \\ r_{21} & r & \ldots & r_{2} \\ \ldots & \ldots & \ldots & \ldots \\ r_{m1} & r_{m2} & \ldots & 1 \end{bmatrix},$$

where:

$$\bar{r}_{jp} = \frac{(-1)^{j+p}\, det(R_{jp})}{det(R)}$$

$det(R)$ – correlation matrix indicator,
$det(R_{jp})$ – matrix indicator after the removal of j in this row and p in this column.

Subsequently, elements on the main diagonal satisfying the inequality, that is, those with values exceeding the predetermined threshold (typically chosen based on practical considerations), are identified. Starting from the largest value, these elements are systematically removed from the set of indicators in a stepwise manner. The remaining indicators in the analyses are either uncorrelated or weakly correlated (diagnostically), signifying their unique information relevance in the context of the analyzed phenomenon. This elimination process persists until the main diagonal of the inverse matrix contains values below the established threshold (Dziechciarz 2002).

To formulate an index of technological advancement, a measurement model was established through structural equation modeling (SEM). It is worth emphasizing that SEM requires a larger sample (>500), which, according to Westland (2010), is often a problem for many researchers. However, in the literature there are sources that state in the case of confirmatory factor analysis (CFA), a sample of 50 or 100 people is enough (Gunawan et al. 2021).

This approach facilitates CFA for estimating latent constructs, also known as latent variables. A latent variable is not directly observable in the dataset; rather, it is an inferred common factor derived from other variables, indicating the model's effects (Hoyle 1995, Grace 2006, Kline 2010, Hoyle 2011, Byrne 2013). In the present study, this variable represents the level of technological advancement.

The model incorporates observable variables – indicators of technological advancement – comprising those that persist following the data reduction process. For the developed model of technological advancement, the model's goodness-of-fit parameters were evaluated, based on the criteria proposed by Hu and Bentler (1999):

- root mean square error of approximation (RMSEA): This metric assesses the discrepancy between the model and the observed data. A lower RMSEA value indicates a better model fit. A threshold value of 0.08 is commonly adopted, with values <0.08 indicating a good fit to the data.
- $\chi\chi^2$ (chi-square): This test statistic is utilized to evaluate the fit of the model to the data. In a well-fitting model, the p-value for the χ^2 statistic should be insignificant.
- χ^2/df (chi-square divided by degrees of freedom): This ratio, obtained by dividing the χ^2 statistic by the number of degrees of freedom, should ideally be <3 (with an acceptable threshold <5) for a satisfactory model fit.
- Comparative Fit Index (CFI): This index assesses the relative goodness of fit of the hypothetical model to the data. CFI values range from 0

to 1, with higher values indicating a superior model fit. Thresholds of 0.90 or 0.95 are commonly used, where values above these thresholds are considered indicative of a good fit.

– Standardized root mean square residual (SRMR): This indicator, representing the mean standardized square of the residuals, gauges the overall fit of the model. A lower SRMR value suggests a better fit, and values <0.08 are typically regarded as indicative of a good fit to the data.

Descriptive statistics

In the initial phase, basic measures of descriptive statistics were examined, as detailed in Table 3. Across all 25 analyzed indicators, the coefficient of variation was consistently constant at 0.25 and, occasionally, was higher, indicating a substantial variability in the results.

Reduction of variables

To assess the interdependence between variables, an analysis of the inverse correlation matrix was carried out. A threshold value of 5 (r_0) was selected, considering the robust correlations among indicators. Given that many indicators were combinations of several simple indicators, the threshold of 5 was deemed optimal to mitigate collinearity in the model. Following the analysis, 18 out of the 25 indicators were retained for further examination, with the following ordinal numbers: 1, 2, 3, 4, 6, 10, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25.

Creating a model of technological advancement teacher

In the initial step, the CFA model included 18 variables retained after data reduction. However, this model demonstrated an inadequate fit to the data: χ^2 (135) = 637; p < 0.001; χ^2/df = 4.72; CFI = 0.186; RMSEA = 0.169; SRMR = 0.151. Consequently, modifications were introduced to the model based on modification indices and path analysis. Variables insignificantly related to the latent variable were excluded, and additional correlations between variables were incorporated following modification indices.

Table 3. Descriptive statistics of the analyzed parameters (N = 130).

Indicator	Symbol	M	Me	SD	Sk	Kurt	Min	Max	V
1	WP3	1.35	1.00	1.22	2.03	5.71	0.00	7.00	0.90
2	WT1	46.62	50.00	26.51	0.17	−1.07	0.30	90.00	0.57
3	WT2	26.94	0.00	35.02	0.98	−0.42	0.00	100.00	1.30
4	WC2	3.15	3.00	0.79	−0.57	−0.38	1.00	4.00	0.25
5	WE2	1.49	1.45	0.91	0.54	−0.49	0.20	3.60	0.61
6	WO1	16.54	18.00	6.74	−1.00	−0.34	0.00	22.00	0.41
7	WI1	0.77	0.75	0.43	0.23	−0.25	0.00	2.00	0.56
8	WP1	0.47	0.10	0.68	2.27	6.25	0.10	4.00	1.45
9	WP5	1.17	1.00	0.92	1.36	2.07	0.00	4.75	0.79
10	WI6	1.36	1.31	0.75	0.52	0.69	0.00	3.75	0.55
11	WE1	13.01	7.62	16.04	3.03	10.90	0.00	100.00	1.23
12	WI4	3.90	1.68	7.67	5.15	31.36	0.00	61.70	1.97
13	WI3	20.44	22.00	11.54	0.10	−1.00	1.50	44.00	0.56
14	WO4	44.29	32.50	40.96	1.78	4.18	0.00	240.00	0.92
15	WI5	0.39	0.38	0.31	3.74	22.27	0.00	2.50	0.79
16	WC1	1.62	1.09	1.78	3.39	15.92	0.00	13.00	1.10
17	WA1	17.19	14.00	15.26	1.46	1.88	1.00	60.00	0.89
18	WI2	1.88	1.75	0.63	0.39	0.49	0.50	4.00	0.34
19	WP4	1.21	0.75	1.26	1.79	3.38	0.00	6.10	1.04
20	WP2	1.23	1.10	0.92	1.00	0.84	0.20	4.10	0.75
21	WO2	16.04	16.00	8.55	0.89	0.55	0.00	40.00	0.53
22	WO3	1.29	0.88	1.45	2.97	9.90	0.00	8.60	1.12
23	WP6	0.56	0.11	1.49	6.84	55.55	0.00	14.00	2.66
24	WE4	0.41	0.09	0.89	4.36	23.72	0.01	6.80	2.17
25	WE3	2.44	0.50	5.92	4.18	18.76	0.00	36.00	2.43

Table 4. Description of technological advancement indicators.

No.	Symbol or formula	Description
10	WI6 = WI1x WI2	The product of independence for creating and using own presentations, worksheets, and independence for frequent use of readymade materials
15	WI5 = WI1/4-WI2	The quotient of the sum of points for the independence of creating and using own presentations and worksheets and the difference between the value of four points (very high frequency of use of four readymade materials from the Internet) and the actual independence of frequent use of these four readymade materials from the Internet (games, maps, videos, tutorials)
17	WA1	Number of days of adaptation to distance education
18	WI2	Total points for independence in using the Internet: games (max. 1 pt); maps (max. 1 pt); videos (max. 1 pt); tutorials (max. 1 pt) at frequency: 1 pt when always doing it; 0.75 pt when doing it very often; 0.5 pt often; 0.25 pt occasionally
19	WP4	The quotient of multiplication of the independence of using readymade materials from the Internet and the number of hours of training per week, and the number of hours per week needed to prepare worksheets
24	WE4 = WP1x (WT1 + WT2)	The product of the number of learned and applied programs and the sum of the belief in the ability to develop skills and the belief in the effectiveness of distance education

The final model featured 6 indicators of technological advancement (Table 4): WI6 (item 10), WI5 (item 15), WA1 (item 17), WI2 (item 18), WP4 (item 19), WE4 (item 24). This refined model exhibited a good fit to the data: χ^2 (8) = 5.04; p = 0.753; χ^2/df = 0.63; CFI = 1.00; RMSEA < 0.001 [95% CI = 0.00; 0.07]; SRMR = 0.029. Utilizing these indices, the formula for *Technological Advancement Index* (TAI) was derived, allowing calculation of the technological advancement level for each geography teacher individually.

Formula

Technological advancement level =
0.73 × WI6 + 0.91 × WI5 – 0.19 × WA1 + 0.42 × WI2 + 0.28 × WP4 + 0.23 × WE4

Results

Based on the regression coefficients obtained (Table 5) and the CFA model (Fig. 1), it was demonstrated that the most influential predictor of technological advancement was independence, as indicated by three factors: WI5 (item 15) with a loading value of 0.91, WI6 (item 10) with a loading value of 0.73, and WI2 (item 18) with a loading value of 0.42. These factors pertain to teachers' confidence in creating their own presentations and utilizing readymade teaching materials acquired from the Internet, including games, videos, maps, and tutorials. Teachers commonly and frequently employ digital maps, with 27% doing so occasionally. Additionally, >80% occasionally use tutorials to develop their own maps. Consequently, higher independence corresponds to an elevated level of technological advancement.

A less potent predictor of technological advancement, with a value of 0.28, is the proficiency index WP4 (item 19). Similar to the three aforementioned indicators, it is linked to

Table 5. Regression coefficients of the CFA (confirmatory factor analysis) model of the level of technological advancement.

Indicator	*B*	SE	*Z*	*p*	*β*
WI6	0.55	0.07	8.24	<0.001	0.73
WI5	0.28	0.03	9.99	<0.001	0.91
WA1	−2.90	1.42	−2.04	0.042	−0.19
WI2	0.27	0.06	4.65	<0.001	0.42
WP4	0.35	0.12	2.97	0.003	0.28
WE4	0.20	0.09	2.35	0.019	0.23

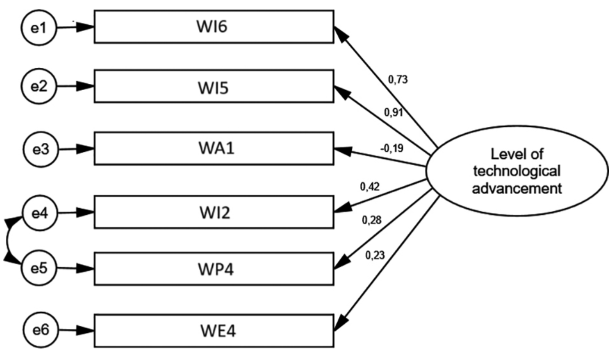

Fig. 1. Confirmatory factor analysis (CFA) model for technological advancement level.

independence. However, it also considers the number of hours per week allocated to training and the preparation of instructional materials. This implies that a higher frequency of using readymade materials and investing time in training, coupled with a reduced time commitment to material preparation, corresponds to increased proficiency and technological advancement levels. The WP4 indicator maintains average values, but 8% of the surveyed teachers exhibit the highest values (Table 6).

It was established that the predictor with a lower factor loading value of 0.23 is the efficiency index WE4 (item 24). Its magnitude relies on the proficiency of learned and applied programs, as well as belief in the high effectiveness of distance education and the capacity to develop geographic skills. The value of WE4 does not see a significant increase with advancement, as it is influenced by the substantial percentage (65%) of teachers who perceive distance education as ineffective. According to these teachers, the

Table 6. Average values of predictors in relation to levels of teacher technological advancement.

Levels of technology proficiency of geography teachers	Number of teachers (N = 130)	Means for WI5 for range 0–2.5	Means for WI6 for range 0–3.75	Means for WI2 for range 0.5–4.0	Means for WP4 for range 0–6.1	Means for WE4 for range 0–6.8	Means for WA1 for range 1.0–60.0
(−9.1; −10.60)	6	0.25	0.84	1.54	0.71	0.05	60.0
(−7.61; −9.0)	2	0.42	1.47	2.00	1.23	0.08	60.0
(−6.1; −7.60)	2	0.50	1.75	1.50	2.85	0.70	52.5
(−4.61; −6.0)	2	0	0	0.87	0.09	0.09	30.0
(−3.1; −4.60)	12	0.27	1.03	1.95	0.74	0.11	30.0
(−1.61; −3.0)	18	0.29	1.12	1.95	1.27	0.19	24.1
(−0.01; −1.60)	22	0.28	1.01	1.76	1.00	0.44	15.7
(0.01; 1.60)	38	0.39	1.44	1.84	1.09	0.36	8.84
(1.61; 3.0)	19	0.45	1.69	1.67	1.39	0.97	4.29
(3.1; 4.60)	7	0.67	2.50	2.39	2.20	0.53	11.7
(4.61; 6.0)	2	1.12	2.25	2.75	3.75	0.65	4.00

Table 7. Percentage of teachers using maps with different functionality according to their level of technological advancement.

Functionality of maps	Percentage of teachers by grade level				
	−6, 1; −10.60	−3, 1; −6.0	−0.01; −3.0	0.01; 3.0	3.1; 6.0
Map in paper textbook – page range sent	6	0	0	0	0
Map in exercise book/worksheet – range of tasks sent	55	33	25	2	0
Map in a Polish TV program (online lessons on TVP)	44	16	21	7	41
Map in a movie (YouTube)	83	63	79	76	66
Map in an e-book	28	25	37	40	50
Map on the geography24 website	0	58	12	25	25
Map in a multimedia presentation – giving Methods – lecture	61	96	84	70	75
Map in quizzes, e.g., Wordwall, Quizzes, interactive exercises	44	39	46	43	67
Map in tests, e.g., testportal	6	29	7	9	0
Map in interactive applications, e.g., earth.nullschool.net	29	4	0	2	15
Google maps, Google Earth	0	4	7	17	5
Maps in map services	0	8	9	4	0
Map in Internet atlas, e.g., meridian, maplab	0	8	0	4	21
Maps on the websites of institutions, e.g., Central Statistical Office (CSO)	0	0	10	5	7
Map in geoportal – solving a problem, creating new knowledge	0	0	0	8	46
Map in GIS (geographic information system) and tutorials – creating new knowledge, e.g., in the form of a map	0	0	0	12	65

formation of geographic skills is deemed possible at a range of 26–50%. The WA1 indicator (item 17), associated with adaptation time, displayed the least correlation with the model. This variable exhibited a negative relationship with the latent variable (−0.19), signifying that the lower the level of technological advancement, longer the adjustment time (Table 6).

The division of advancement into 11 intervals with equal values exhibited significant variation among respondents (Table 6). Accordingly, and in alignment with the study's objective, the range of map use was considered (Table 7), leading to the identification of five levels of technological advancement.

The first level (−6.1; −10.6) encompasses 8% of surveyed teachers who adapted to the new situation within 2 months (Table 6). This group primarily communicated terms of reference to students through mail and electronic journals. Maps were present in pre-made presentations and videos, indicating an administered use.

The second level (−3.1; −6.0) includes 11% of teachers (Table 8) who adapted within 30 days. They managed their time more efficiently compared with the first group but operated at a similar level of independence. Maps continued to appear mainly in finished materials.

The third level, with a negative TAI between −0.01 and −3.0, characterizes 31% of all respondents. This group exhibits elevated WI2 values, indicating the ability to independently find and use readymade materials in most lessons. In this group, the percentage of teachers using presentations decreases in favor of videos, games, or map services (Table 7).

At the fourth level, there is a positive level of technological advancement, ranging from 0.01 to 3.0, with 44% of all respondents falling into this category. They demonstrate independence

Table 8. RIGMA (recommendation, imitation, gamification, mobilization, action) model with levels of technological advancement of geography teachers.

Ranges of the level of technological advancement of geography teachers	Percentage of teachers	The concept defining a given level of advancement and the corresponding SAMR level (substitution, augmentation, modification, redefinition)	Description of their actions by teachers	Criterion for evaluation of students	Description/interpretation of actions during distance education by teachers
−6.1; −10.60	8	**R**ecommendation (SAMR – Substitution)	*'I send recommended sites'* *'the student has to search on his own'*	*'independence in searching and sending completed worksheets'*	*'aimlessness and confusion'*
−3.1; −6.0	11	**I**mitation (SAMR – Substitution)	*'students search the Internet for their own interpretations'*	*'reproducible knowledge'*	*'willingness to devote time'*
Minimum range of skills					
−0.01; −3.0	31	**G**amification (SAMR – Augmentation)	*'gamification'*	*'independence of tasks and work performed'*	*'dependence on technology and constraints'*
0.01; 3.0	44	**M**obilization (SAMR – Modification)	*'work in such a way as to interest, I propose problematic tasks'*	*'engagement in lessons', 'degree of use of ICT for analysis and inference'*	*'mobilization'* *'New materials and tools give me opportunity'*
3.1; 6.00	6	**A**ction (SAMR – Redefinition)	*'out-of-the box approach to the topic'* *'creative self-work'*	*'responsibility and regularity'*	*'passion'*

in finding readymade materials and frequently using them in lessons. One in three teachers achieves the highest efficiency rate in this group, using 3–4 learned and applied programs, while simultaneously holding a strong belief in the effectiveness of distance education. A more advanced level of technology is evidenced by the use of maps from Google Maps or Google Earth, online atlases, geoportals, or map services. In this group, 16% of teachers use tutorials to create their own maps, showcasing a higher level of map functionality.

The final fifth level is distinguished by high values for the proficiency rate. This means that 6% of teachers simultaneously take training courses, utilize the digital map software they have learned, and require minimal input in preparing time-consuming worksheets. Although the extent of map use is not as high as at the fourth level, there is a clear increase in the percentage of teachers using tutorials and creating digital maps based on them (Tables 6 and 7).

Hence, elevated predictor values are observed solely at the positive advancement level, encompassing independence at all levels (0.01–6.0) and proficiency at 3.1–6.0 (Table 6). Achieving high efficiency is particularly challenging, as the highest values were attained exclusively by teachers within the range of +1.61 to +3.0. Additionally, a consistent pattern emerges, indicating that as technological advancement advances, the utilization of maps in geography lessons also increases (Table 7).

A qualitative examination of teachers' teaching job descriptions, encompassing communication, teaching methodology, and assessment, enabled us to corroborate the findings presented in Tables 6 and 7. This validation process facilitated the development of the RIGMA model – a framework designed for evaluating teachers' technological advancement in distance education (Table 8).

Drawing from the survey results, it was established that the majority of geography teachers exhibit a medium–low level of technological advancement. One-third of geography teachers align with the G (Gamification) level, indicating a modest yet negative level of advancement, implying compliance with reproductive tasks coupled with the utilization of quizzes. Nearly half of the teachers fall within the fourth level, denoted as level M (Mobilization), showcasing increased advancement and teacher engagement. This level involves extensive use of maps with diverse functionalities, with a key emphasis on independence and technological efficiency.

Discussion

The topic of teachers' technological competence has been discussed in the literature for over a decade, as evidenced by works such as Wolf (2006), Lee and Rha (2009), Bose (2014), Ash et al. (2016), Cole et al. (2017), Rehn et al. (2018), and UNESCO (2018). However, it gained particular prominence at the onset of the pandemic, identified by many, including Fuller et al. (2021), Scully et al. (2021), Bakar et al. (2020), and Batty and Hall (2020), as an area requiring further development. The discourse not only touched upon the lack of digital skills among teachers (Greenhow et al. 2021) but also highlighted the reliance on basic technological skills (Lubuva et al. 2022), an aspect partially supported by the findings presented in this study (refer to Tables 6–8). It is noteworthy, however, that the surveyed geography teachers exhibited a significantly higher level of technological advancement compared with teachers in other subjects (Fila et al. 2020, Herold 2020, Ptaszek et al. 2020 among others).

When comparing different groups of teachers, we must also remember that 130 geography teachers participated in the research, out of 4000 people who had access to Facebook groups for geographers. However, access to social media does not mean problems with using Internet connections. Buchner et al. (2020) indicate that the problem of Internet connection concerned 32% of teachers, and 56% solved it on an ongoing basis. It is therefore difficult to determine the level of advancement of those teachers who had problems with the Internet or did not use it.

Studies conducted at the onset of the pandemic (e.g., Bakar et al. 2020, Corbera et al. 2020) suggested that the establishment of a flexible communication process was facilitated by teachers' prior experience with email or other instant messaging tools. Consequently, teachers were prepared to engage with students (Cole et al. 2017), providing ongoing feedback that could foster continued effort and accountability (Daniels 2020). Earlier publications underscored personal qualities like commitment (Lee et al. 2018) and communicative accessibility (Inman et al. 1999). However, the results from this study do not affirm the hypothesis that traits such as commitment and communication are indicative of a high level of technological advancement. The data presented in Table 8 suggest that, at the level of recommendation and imitation, corresponding to a negative level of technological advancement, these traits may suffice. However, other attributes that clearly correlate with higher technological advancement are necessary to sustain student engagement.

The first crucial personal characteristic of a teacher is the ability to independently apply technology. Independence is defined as 'a person's unique disposition to guide their own behavior' (Sekułowicz, Oleniacz 2012, p. 9). It can be viewed as a life attitude intertwined with autonomy and self-determination. At the lowest level of technological advancement, teacher independence is demonstrated through independent thought and action without the need for external assistance. The absence of independence may lead to frustration and demotivation in the face of new challenges (Gewertz 2020), as is evident at the lowest levels of the RIGMA model (Table 8). This is because expecting students to be independent is unrealistic when the teacher lacks independence. Therefore, Wolf's (2006) assertion that distance education necessitates adequate preparation, with a minimum set of skills encompassing computer, Internet, and online applications, holds true. The absence of basic technical skills constitutes a fundamental limitation in remote work (Rockwell et al. 1999), hindering, among other things, the selection of appropriate distance learning models (Taylor 1995, 2001, Parmigiani et al. 2021) or the creation of high-quality educational materials (Lee, Rha 2009).

The second characteristic is efficiency, which is particularly prominent at medium levels of technological advancement. It can also be achieved at lower levels (Table 6), as it is associated not only with independence regarding programs already in use, such as those for analysis or mapping, but also with the belief in the effectiveness of distance education. This determinant of remote work is highlighted in numerous studies (e.g., Holmberg 1989, Bernard et al. 2004, Cavanaugh et al. 2004, Cook, Babon 2017, Piotrowska, Abramowicz 2021). Low beliefs about the effectiveness of distance education may stem from various factors, including the challenge of teachers adapting to changed roles and transitioning to student-centered teaching (Yang, Cornelious 2004), which might be linked to underestimating the importance of the classes or online courses being conducted (Inman et al. 1999). This, in turn, could contribute to lower self-assessment of their own effectiveness (Burns 2011). Attitudes and beliefs are often referred to as 'second-order barriers' (Winter et al. 2021), and understanding these beliefs is crucial as they are connected, according to Fives and Buehl (2012), to student performance. The teacher's appropriate approach to work during distance education forms the foundation of technological advancement, expressed through mobilization (Table 8). Approximately 15% of teachers, as illustrated in the study (Table 6), exemplify a positive approach and belief in the effectiveness of their work. A similar percentage of teachers expressing high confidence in technology use was reported in a study by Saubern et al. (2020).

The third characteristic is proficiency. This study posits that technological advancement comprises independence and the efficiency of action, stemming not only from beliefs but primarily from knowledge and skills acquired during training. The need for support in enhancing teachers' digital competence has been a significant concern for many years (Greenberg 1998). This need for teacher support was also underscored in the UNESCO 2023 report, emphasizing the importance of adequate ICT training and highlighting that only half of the countries have established ICT teacher development standards.

However, recognizing that all three personal qualities require motivation, training should be geared toward fostering positive attitudes toward ICT usage and altering mindsets (Basargekar, Singhavi 2017). Proficiency emerges at the highest levels of advancement (Table 6) and is characterized by the deliberate use of technology, expanding the repertoire of digital maps employed. The amalgamation of independence, efficiency, and systematic training enables an active and creative approach in geography lessons. Teachers marked by the highest proficiency describe their work approach as a passion, and owing to their elevated technological advancement, they leverage maps to their fullest potential. According to Winter et al. (2021), experienced teachers can serve as role models by passionately engaging in their work.

Conclusions

In the 21st century, educational systems are widely acknowledged to undergo transformative changes, preparing citizens for lifelong learning. UNESCO's 2018 report introduces the ICT Competency Framework for Teachers (CFT), identifying 18 competencies that teachers worldwide should strive for. The global shift toward a knowledge-based society necessitates an understanding of how traditional (text-based) and new (digital) technologies can enhance the classroom for an improved learning environment. The quality of this integration hinges on the technological advancement of teachers. Their role extends beyond communication and task delegation; they must create a dynamic and creative learning environment.

Considering the enduring significance of distance education and the necessity to prepare students for similar situations in the future (Speck 2020), it is valuable, as suggested by Piotrowska et al. (2022), to conduct ongoing professional development for teachers. This involves continuously updating knowledge related to geo-information technologies within the context of school practices and regulations. Professional development for teachers serves as a pivotal element in enhancing education. Its impact, however, is contingent on a focus on specific changes in teaching methodologies. One such change could be the cultivation of three essential personal qualities in future teachers: independence, efficiency, and proficiency.

Assessing the level of advancement can be facilitated by using the RIGMA model, which considers not only proficiency levels and the ranges of values for individual indicators but also emphasizes the significance of work methodology and the accompanying emotions. It is noteworthy that validation of the RIGMA model occurred through three key components: content knowledge, technology, and pedagogy.

The significance of these components has been underscored by Mishra and Koehler (2006), among others. Selwyn (2019) envisions two distinct scenarios for teacher improvement. In the first, technology empowers teachers to engage in meaningful activities of organization and inspiration, while in the second, teachers may risk losing their autonomy as they conform to technology-driven expectations, such as assessing students through online tests. There is emerging evidence that classroom management has, in some cases, been reduced to performing basic technical functions (Watermeyer et al. 2021, among others). However, it is crucial to note that the challenge lies not in technology itself but in how it is incorporated into course design and delivery.

As highlighted by Cichoń (2021), the focus should not merely be on using multimedia presentations to convey messages, but rather on leveraging technology and digital materials for collaborative discussions, analysis, and problem-solving with students. Although some believe that technology can enhance the quality of education, it is prudent to agree with Palloff and Pratt (2000) that *technology does not teach; only effective teachers do* (p. 4). Therefore, distance education consists of four key elements: subject knowledge, technology, and pedagogical and technological skills.

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Authors contribution

Małgorzata Cichoń: conceptualization, methodology, software, validation, formal analysis, writing – original draft, writing – review & editing, visualization, project administration, Jakub Sypniewski: conceptualization, methodology, data curation, writing – review & editing, Iwona Piotrowska: methodology, writing – review & editing.

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