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Teachers' in-service training in geographic information system (GIS) and different integration behaviors in lectures

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Abstract

This project explores whether and how in-service training for Taiwan's secondary school geography teachers has affected their adoption of geographic information system (GIS) in lectures. According to our survey analysis, active GIS adopters show a greater propensity for teaching about and with GIS. It does not matter whether GIS is mandatory in certain lectures; the active adopter would choose to use it for teaching. Passive adopters would teach about and with GIS only in lectures for which its use is mandatory. Compared with the other types, laggards are less likely to use GIS. The success of in-service training does not lie in its offering of GIS skills and knowledge. What is more important is that the training has been designed to cultivate teachers' GIS technological pedagogical content knowledge (TPACK) that makes teachers ready to use GIS in their lectures.

1. Introduction

A geographic information system (GIS) is a system of hardware and software used for storing, displaying and analyzing spatially referenced data. In the research on geography education, experts believe that GIS can be useful for teaching geography (Kerski, 2003; Kerski et al., 2013). For instance, GIS can help visualize spatial data quickly and efficiently. This further allows students to observe the relationship between various spatial phenomena. Through this process, students can develop critical spatial thinking abilities and higher-order thinking skills (HOTS) such as problem-solving and decision-making capability (Yap et al., 2008; Bednarz and van der Schee, 2006; Kerski et al., 2013).

In fact, GIS has been used in higher education since it came into existence in the 1960s. However, it is not until the early 1990s that GIS started to be used in secondary education (Kerski et al., 2013). In Kerski et al.'s

(2013) global survey of the usage of GIS in secondary education, they note that only very few countries have actually included GIS in formal national curricula with Taiwan, Finland, India and South Africa being these few examples.

Although the achievement of Taiwan in GIS education appears to be impressive (Kerski et al., 2013; Wang and Chen, 2013), this paper seeks to explore how this has been conducted from a practical perspective. In other words, it is one thing for GIS to be included in the national curriculum, and it is another for GIS to be actually used in secondary education. The concepts of "teaching about GIS" and "teaching with GIS" have been advocated by geography educators and researchers as essential elements in successful GIS integration into geography education (Kemp and Goodchild, 1991; Sui, 1995; Rød et al., 2010). If teachers focus on teaching GIS as a technology, such as how to handle, represent, visualize, and analyze spatial data, they are teaching about GIS (Sui, 1995). If the deliverance of geographic knowledge is the primary goal and GIS is applied to facilitate this process, teachers can be said to be teaching with GIS (Sui, 1995). In Kerski et al.'s (2013) global survey, they found that teaching with GIS is more widely seen in secondary education than teaching about GIS. We intend to uncover how teaching with GIS and teaching about GIS are practiced in Taiwan's secondary schools. Furthermore, by showing how in-serving training has influenced GIS adoption in secondary education, we believe that the Taiwan experience serves as a good model for GIS promoters around the world to follow.

The implication of this paper is not just practical for GIS promotion. It also corresponds to some scholarly efforts in the GIS discipline to re-connect the technology with its root in geographic knowledge (Bertazzon, 2013; Schuurman, 2000; O'Sullivan, 2006). The importance of social and political conditions that enable the growth and spread of GIS is manifested in Taiwan's experience.

In the next section, we begin by examining the national curriculum and the measures, including mainly in-service training, that have been set up to encourage GIS education in secondary schools. In the third section, we explore the implementation outcome, that is how teachers actually teach with GIS and teach about GIS in lectures. The data are from a 2011 national census conducted in Taiwan among approximately 1,530 senior high school geography teachers. The response rate was 47.52%. After data collection and organization, we were able to analyze data gleaned from 725 respondents. We found that teachers can be categorized into three types when it comes to their GIS adoption: active adopters, passive adopters, and laggards. The fourth section explores what leads to these variations in integration behaviors. We find out that in-service training for teachers has a significant impact on GIS adoption in secondary education. The success of in-service training does not lie in its offering of GIS skills and knowledge. What is more important is that the training has been designed to cultivate teachers' GIS technological pedagogical content knowledge (TPACK) that makes teachers ready to use GIS in their lectures.

2. The promotion of GIS in secondary education

As Kerski et al. (2013) rightly point out, to fully realize GIS's potential in education, there needs to be support from the government and higher educational institutes. In fact, the creation of a stand-alone policy encouraging GIS usage in secondary education will not work well. Various kinds of technological, societal and educational policies need to be set up to generate favorable conditions to effectively promote GIS adoption. Due to limited space, however, this paper does not tackle the complexity of various policy designs and social conditions that can help maximize GIS integration. Rather, we focus on the educational policy, that is, the inclusion of GIS in the national curriculum guidelines.

Taiwan's senior high school education is approximately equivalent to 10th through 12th grade in the American system. The concept of GIS was first incorporated into Taiwan's national geography curriculum guidelines in 1999. The guidelines called for a three-hour GIS class session for 12th graders wishing to major in the humanities or social sciences at university

level. The proportion of GIS learning further rose in the 2006 and 2010 curriculum guidelines. One-third of the geography course in the first semester of the 10th grade is related to GIS. GIS applications in various areas of life are taught in these classes (Lay et al., 2013a).

While the 1999 curriculum guidelines emphasize the teaching of GIS concepts, the 2006 and 2010 guidelines add examples of how GIS can be applied to monitor floods, diseases, mudslides, diseases, urban planning, among other topics. GIS application is stressed in thematic lectures on topography, medical geography, spatial planning, demography, and other aspects of the subject because these themes are believed to be helpful in stimulating students' spatial thinking. Moreover, the 2006 and 2010 guidelines advocate hands-on experience in operating the relevant hardware and software. There is a trend toward project-oriented teaching which enables students to use GIS to solve problems in geography classes (Lay et al., 2013a).

Wang and Chen (2013) mention that, based on the national curriculum guidelines, learning GIS in high school is anticipated to be "cognitive, affective, and psychomotor". Hence, apart from teaching concepts related to GIS (i.e., teaching about GIS), teachers are required to impart geographic knowledge by using (i.e., teaching with) GIS. While the curriculum was very ambitious, there was concern that teachers do not have sufficient professional knowledge, practical skills and experience to achieve these goals.

In Kerski et al.'s (2013) global survey, they found that insufficient GIS education for pre- and in-service teachers represents a hurdle to successful GIS implementation in secondary schools in countries such as South Korea, Norway, and Canada. In-service training for geography teachers is thus proposed as a vital measure to minimize the gap between policy ideals and practices.

In Taiwan, the Department of Geography at the National Taiwan University (NTU) is the major institution entrusted by the Ministry of Education (MOE) to undertake the promotion of GIS education, and it provides GIS training for teachers for that purpose (Chen, 2012). This kind of top-down approach, with the financial support from the government, working in collaboration with GIS experts in higher education to design in-service training for high school geography teachers is in line with international practice. For instance, in the US National Research Council's (2006) report on *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, this kind of cooperative model is also recommended.

It is important to note that a large number of Taiwan's geography teachers hold a master degree. In fact, all of Taiwan's geography teachers are legally required to major or minor in geography at university level in order to obtain the certificate for working as geography teachers later on (Lay et al., 2013a). This indicates that the nation's geography teachers are not only educationally well prepared, but also specialize in the area that they teach. As the 2010 national curriculum guidelines in Taiwan make reference to teaching about and with GIS, these professional geography teachers would try to meet these expectations. It is equally important to note that although teachers can voluntarily decide to attend in-service training or not, the MOE does provide an "incentive" to encourage participation: that is, attendance can be recognized as a civil servant's learning hours, which plays a role in a teacher's promotion.

Apart from providing in-service training, the NTU's Department of Geography is involved in creating teaching modules, software, geographic data, maps, Keyhole Markup Language Zipped files (KMZ) for customizing Google Earth pages, etc. Teachers are encouraged to use Google Maps, Google Earth, and other free online platforms or software (e.g., QGIS, gvSIG) as these free wares can lower the barriers to using GIS. This is particularly vital for schools where a shortage of GIS software and GIS-based resource packages exists. This development is also in line with practices in other countries, in which GIS and related spatial technologies (e.g., Google Earth, smartphones) are used for teaching and learning (Kerski et al., 2013).

GIS EDU (http://gisedu.tw) is a platform created by the NTU's Department of Geography to freely disseminate learning materials and spread GIS-related news. The Department also

hosts competitions for drawing maps or creating teaching modules that are integrated with GIS. It is expected that competitions can incentivize teachers and their students to become more engaged in applying GIS to analyzing various social and natural phenomena. The usage of national competitions is acknowledged as a useful means to promote GIS in Kerski, et al.'s (2013) global survey. Apart from Taiwan, countries such as Canada and Australia also hold national GIS competitions.

After introducing the measures that aid the implementation of the national curriculum guidelines, we now turn to the question of whether these measures have made actual impacts. We expect a variation of integration behaviors to exist. The following section identifies three types of integration behavior in the classroom.

3. Three types of GIS adoption

In this study, we try to differentiate teachers' GIS integration into "compulsory" and "non-compulsory" units. The former category refers to the unit on cartography/geographic information in the 10th grade. Following the national curriculum guidelines, teachers should, in principle, teach about and/or with GIS in the compulsory unit. The matter of whether or not Taiwan's high school geography teachers have met this expectation is to be investigated.

It is also interesting to explore whether teachers would teach about and with GIS in units for which GIS is not mandatory according to the national curriculum guidelines. Examples of "non-compulsory units" are human geography, world geography, Taiwan geography, and China geography.

Kerski et al. (2013) observe that teaching with GIS is more dominant in secondary education than teaching about GIS around the world. However, we posited that most of Taiwan's teachers may have more experience teaching about GIS than teaching with GIS because teaching concepts and principles are supposed to be easier than actually using the technology to explore geographic knowledge. The following empirical analysis will help clarify this.

Latent class analysis (LCA) was applied to construct the typology of integration (McCutcheon, 1987). The results revealed classes that are scoring patterns for the four manifest variables of teaching about GIS, teaching with GIS, using GIS in compulsory units, and using GIS in non-compulsory units. These measures are specified below.

To assess teaching about GIS, teachers were asked to indicate whether they "teach how to use GIS," "introduce GIS data," and "teach how to collect GIS data". Teachers with these experiences were coded 1, otherwise 0. Overall, 77% of teachers taught about GIS. Similarly, teaching with GIS was measured by inquiring whether teachers "use GIS to aid teaching" and "use GIS to make thematic maps for lecturing". Seventy percent of teachers taught with GIS.

In addition, we investigated the usage of GIS in the compulsory unit. A respondent who used GIS in this unit was coded 1, otherwise 0. A large number of respondents (80%) have used GIS in the compulsory unit.

There are also lectures for which GIS is not compulsory; but if a teacher has used GIS in those sessions, this is an indicator of his/her usage of GIS as an aid in imparting geographic knowledge. Only 38% of the respondents have used GIS in non-compulsory units.

The missing data treatment method applied in this study is multiple imputation (Rubin, 1987). Following Graham et al. (2007), 100 datasets were imputed for analysis. The statistical modeling program used in this study was Mplus Version 7.0. The statistical significance was determined at $p < .05$.

Since the four manifest variables in this study are dichotomous (i.e., 0/1), LCA was performed to discern the typology of GIS integration in teaching. In addition to entropy, the following information criteria were evaluated to determine the number of latent classes: Akaike information criterion (AIC), Bayesian information criterion (BIC), and sample-size adjusted BIC (SSABIC). The lower the information criteria and the higher the entropy, the better the fit of the model. Table 1 shows that the three-class model is optimal as its AIC, BIC, and SSABIC are the lowest, while, at the same time, its entropy is the highest

among the one to four latent class models.

# class	Log-likelihood	DF [a]	AIC	BIC	SSABIC	Entropy
1	-1680	11	3368	3386	3374	NA
2	-1534	6	3085	3127	3098	.817
3	-1515	3	3054	3109	3071	.837
4	-1513	1	3054	3118	3074	.767

DF: Degree of freedom; AIC: Akaike information criterion; BIC: Bayesian information criterion; SSABIC: Sample-size adjusted Bayesian information criterion; NA: Not applicable; a: In two-, three-, and four-class models, the number of parameters estimated as either 1.000 or 0.000 was one, two, and five, respectively. Therefore, one, two, and five degrees of freedom were reclaimed for two-, three-, and four-class models, respectively.
Table 1. Model fit indices of one to four latent class models.
Source: Authors' Survey.

In LCA, one assumes probabilistic rather than deterministic relationships between manifest variables and the latent construct. Thus, Figure 1 displays the probability of using GIS in teaching among the three distinct classes of GIS adopters: active adopters (class 1), passive adopters (class 2), and laggards (class 3).

As they appear to be opposite types, let us begin by looking at the first and third classes. The first class of teachers, which comprises 38.07% of the respondents (276 teachers), is active in teaching about and with GIS. Whether or not GIS is required to be taught in certain lectures, the teachers in this class would use GIS in teaching (Figure 1). Because of their relatively extensive usage of GIS, they are termed active adopters (Bednarz and Witham, 2003).

The third category of teachers is the exact opposite. Made up of 9.97% (65 teachers) of the respondents, laggards do not teach with GIS. Teaching about GIS is supposed to be easier because, without actually knowing how to use it, one can simply describe and explain what GIS is and does. Nevertheless, to teach with GIS requires confidence and actual skills to apply spatial analysis and impart geographic knowledge. This is what laggards seek to avoid. Moreover, laggards do not teach GIS in non-compulsory units. They only teach about GIS in the compulsory unit and with minimum effort.

This third class is the rarest among all the classes (Figure 1).

The second group of teachers demonstrates mixed experiences. The teachers in this second class, which consisted of the most respondents (384 teachers, 52.97%), have taught about and with GIS in lectures. However, as passive adopters, they only do so in classes in which GIS is compulsory (Figure 1).
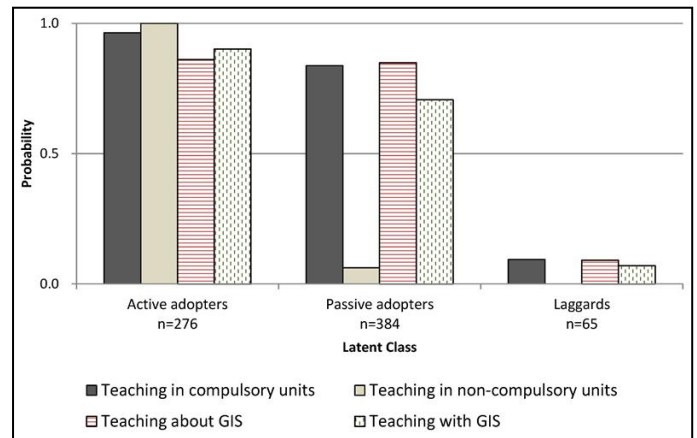

Figure 1. Conditional probability of using GIS in teaching.
Source: Authors' Survey.

The overall propensity of respondents to teach about, rather than with, GIS is well illustrated in Figure 1. This pattern is different from the more widespread pattern in the world in which teaching with GIS is dominant (Kerski et al., 2013). What this finding implies is that Taiwan's teachers have made the existence of GIS known to their students, but they are not prone to actually employing GIS to deliver geographic knowledge. The cultivation and consolidation of teachers' capability to use GIS in imparting geography is thus still an important task for the MOE and NTU in the years to come. We will return to discuss this issue at the end of this paper.

Lastly, Figure 1 reveals that more teachers use GIS in the compulsory units than in the non-compulsory units. Active adopters are interesting as they use GIS in both the compulsory and non-compulsory units. Their usage of GIS in non-compulsory units is even slightly higher than it is in compulsory units.

This is an encouraging development for GIS promoters as it demonstrates teachers' efforts in applying GIS to various parts of their lectures.

4. What characterizes the three classes of GIS integration behavior?

To explore what led to the aforementioned three types of GIS integration behavior, we look into some commonly examined independent variables in both fields.

4.1 Hypotheses

Although teachers' education and technology integration are two separate fields, there is a synergy in the views shared by scholars in these disciplines. In various studies on technology integration in teacher education, it has been pointed out that teachers' belief in applying technology is vital. The existence of the technology hardware, as well as the knowledge of how to use it, cannot lead to effective integration unless teachers believe in the value of integrating it. This echoes Voogt et al's (2013) observation that knowledge and belief are intertwined. Belief about technology and pedagogical belief are important (Voogt et al, 2013). Teachers' belief is generally understood to include dimensions such as self-efficacy, the value of improving students' learning, and belief in the value of technology (Spotts, 1999; Zhoa and Cziko, 2001; Kim et al., 2013). In Spotts's paper (1999), for example, it is found that high-level technology users perceive greater benefits in using the technologies in class than low-level users.

In a similar vein, the concepts of perceived usefulness (PU) and perceived ease of use (PEOU) have been proposed to study various kinds of technology adoption in the well-known technology acceptance model (TAM) (Cheung et al. 2000; Davis, 1989; Fulk et al., 1987; Kelman, 1958; Lee et al., 2003; Song et al., 2009). They have also been tested in the adoption of various e-learning systems, distance learning modules, and, most recently, in GIS (Lee et al., 2011; Sahin and Shelley, 2008; Tselios et al., 2011;

Lay et al., 2013b; Chang et al., 2013). For instance, it has been found that when teachers believe that GIS can benefit teaching (i.e., PU), they are more likely to attend GIS workshops (Lay et al., 2013b). This also helps teachers to actually use GIS in lectures (Lay et al., 2013b). Interestingly, PEOU does not seem to play a vital role in facilitating GIS usage (Lay et al., 2013b). Because the impact of PU and PEOU on the differentiation of GIS integration behavior has not yet been tested, we hypothesize a positive relationship here.

Moreover, because participation in GIS in-service training (i.e., GIS workshops) has been found to have a direct impact on GIS uptake (Lay et al., 2013b), we postulate that workshop attendance will lead to variations in GIS integration behavior.

4.2 Measures

Davis's (1989) six-item measurement of PU has been widely used for examining technology integration. Consequently, we adopted Davis's measurement for our study. PU is assessed by teachers' views on the following aspects: "accelerating teaching," "improving teaching performance," "increasing teaching productivity," "enhancing teaching effectiveness," "making teaching easier," and "usefulness in teaching". Davis's original seven-point scale is simplified to a five-point scale (i.e., strongly disagree, disagree, neutral, agree, and strongly agree) (Malhotra and Galletta, 1999).

The measurement for PEOU was similarly adopted from Davis's (1989) six-item measurement. The items are as follows: "learning to operate GIS would be easy," "finding it easy to get GIS to do what I want GIS to do," "interaction with GIS would be clear and understandable," "finding GIS to be flexible to interact with," "it would be easy to become skillful at using GIS," and "finding GIS easy to use".

To assess workshop attendance, respondents were asked to state the number of times they had attended GIS in-service training during the previous five years. We tested whether in-service GIS training affected the differentiation of GIS adoption behavior. Age, gender, level of education, and school types were controlled. In

terms of age, respondents were divided into two groups of younger or older than 40. With regard to level of education, respondents were divided into those with a bachelor's degree and those with a master's degree or higher. Finally, regarding school types, we examined three kinds of differences: private vs. public schools, senior high schools (which are academic-oriented) vs. vocational schools, and lastly, GIS seed schools vs. non-GIS seed schools. Seed schools are high schools that are designated by the MOE to have their teachers trained in GIS first, and then gradually incorporate GIS into their geography classes (Wang and Chen, 2013; Lay et al., 2013a). With the support of the MOE, 30 seed high schools, out of approximately 500 high schools in Taiwan, have been set up to undertake the mission of promoting GIS. In fact, NTU began by cultivating teachers in these seed schools and is gradually expanding its coverage to include training for teachers in non-seed schools in Taiwan. It is anticipated that active adopters are more likely to come from seed schools than non-seed schools, while laggards may largely come from non-seed schools.

4.3 Analysis and discussions

As summarized in Table 2, two main hypotheses are supported by the statistical data. That is, perceived usefulness of GIS and workshop attendance respectively leads to variation of GIS adoption behaviors. The hypothesis about the impact of perceived ease of use, however, is not supported.

Teachers who participate more frequently in GIS workshops tend to be active adopters, while laggards attend fewer GIS training sessions. In terms of PU, active adopters and passive adopters are inclined to perceive GIS as beneficial in teaching, while laggards are slightly less so. PEOU does not seem to vary greatly among active adopters, passive adopters, and laggards.

Taking control variables into consideration, there is no significant association between gender and age and the differentiation of GIS integration behavior. Education level and school types, however, are associated with the three classes of GIS adopters.

Continuous Variables (mean)	Active adopter	Passive adopter	Laggard	F [a]	P-Value	
Workshop attendance	3.9	3.1	1.5	21.0	<.001	***
Perceived usefulness	23.6	22.7	22.2	7.6	.001	**
Perceived ease of use	20.8	20.7	20.0	0.9	.425	
Categorical Variables (% [b])	Active adopter	Passive adopter	Laggard	χ^2 [c]	P-value	
Gender				1.37	.505	
Female	36.7	54.5	8.8			
Male	40.7	50.0	9.3			
Age group				1.63	.443	
>40 yrs	35.5	55.0	9.6			
<40 yrs	40.0	51.5	8.5			
Education				11.89	.003	**
Bachelor	34.1	52.9	13.0			
Master's or PhD	41.0	53.0	6.0			
School type				9.58	.008	**
Non-GIS seed school	36.6	53.2	10.2			
GIS seed school	46.7	51.4	1.9			
School type II				13.19	.001	**
Private school	34.5	50.5	15.9			
Public school	39.5	53.9	6.6			
School type III				10.92	.004	**
Vocational school	25.2	68.0	6.8			
Senior high school	40.2	50.5	9.3			

*** $p<.001$, ** $p<.01$, * $p<.05$; a: Between- and within-group degrees of freedom are 2 and 722, respectively; b: Row percentage; c: Degrees of freedom is 2.
Table 2. Profile of latent classes.
Source: Authors' Survey.

To explore the relationship between these variables simultaneously, we used latent class path analysis (LCPA). To take classification uncertainty into account, the three-step approach was adopted (Vermunt, 2010). The key findings are summarized in Table 3. Differentiation in integration behavior is found to be significantly influenced by workshop attendance and PU. Education level and school types do have an impact on the differentiation of integration behavior. Their influence, however, is indirect through PEOU, PU, and workshop attendance.

Workshop attendance has an impact on the types of adopters. This suggests that the top-down promotional efforts initiated by the MOE and NTU have been successful in encouraging teachers to become more active in using GIS. We will return to discuss this in detail in the next section of this paper.

Meanwhile, the indirect impact of GIS seed schools is worth mentioning. GIS seed schools appear to live up to the expectation of having their teachers attend in-service training, and this has indirectly contributed to variations of integration behavior. This development is in line with the recommendation made in the US National Research Council's report (2006) which encourages the collaboration between GIS experts in higher education and teachers in "GIS-enabled schools", akin to "seed schools" in Taiwan.

When teachers perceive GIS to be beneficial for teaching, they are more likely to attend in-service training, and, furthermore, to become active adopters. This echoes the existing general findings on the importance of teachers' belief in effective technology integration (Spotts, 1999; Zhoa and Cziko, 2001; Kim et al., 2013). PEOU also has an impact on PU, meaning that when teachers perceived GIS as easy, they would also be more likely to perceive the technology as beneficial for teaching.

Unsurprisingly, teachers with higher educational backgrounds tend to perceive using GIS as easy. Interestingly, teachers from public schools are prone to perceiving the use of GIS as less easy than their peers in private schools. In Taiwan, private schools face more survival stress than public schools, resulting in an education that is highly exam oriented. The ultimate aim of private schools is to ensure that their students can obtain good grades in order to enter universities.

Variable	Perceived ease of use		Perceived Usefulness		# workshop Attendance		Active adopters vs. Laggards [a]		Passive adopters vs. Laggards [a]	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	21.42 ***	0.55	14.74 ***	0.72	7.19 ***	1.11	-3.62 *	1.70	0.26	1.68
# workshop attendance							0.78 ***	0.20	0.71 ***	0.20
Perceived usefulness					0.13 ***	0.04	0.14 *	0.07	0.03	0.07
Perceived ease of use			0.41 ***	0.03	-0.01	0.03	-0.02	0.05	0.02	0.05
Gender										
Female §										
Male	0.48	0.33	0.17	0.24	0.08	0.24	-0.04	0.39	-0.29	0.39
Age group										
>40 yrs §										
≦40 yrs	0.05	0.32	-0.27	0.22	0.29	0.21	0.27	0.39	-0.02	0.39
Education level										
Bachelor's §										
Master's or PhD	0.68 *	0.32	0.10	0.23	0.65 ***	0.20	0.47	0.43	0.34	0.43
School Type I										
Non-seed school §										
GIS seed school	0.54	0.47	0.38	0.35	1.25 **	0.41	6.35	4.44	6.31	4.45
School Type II										
Private school §										
Public school	-0.92 **	0.34	-0.07	0.26	0.81 ***	0.23	0.64	0.41	0.59	0.41
School Type III										
Vocational school §										
Senior high school	-0.87	0.45	-0.32	0.30	0.62 *	0.26	-0.21	0.62	-1.12	0.59

*** $p<.001$, ** $p<.01$, * $p<.05$ (two-tailed tests); SE: Robust standard error; §: Reference category; a: Multinomial logistic regression with laggards as the reference category.
Table 3. Results of latent class path analysis.
Source: Authors' Survey

Relatively speaking, Taiwan's public school teachers are less exam-oriented and have more flexibility in terms of imparting knowledge beyond what will be tested in exams. Public school teachers would have more chances to teach about and with GIS than their peers in private schools. The nature of private school education leads their teachers to care less about GIS. Interestingly, when public school teachers care about GIS, they also come to realize the difficulty of understanding and managing the system. GIS, after all, is a fairly specialized subject; therefore, becoming familiar with it takes time and effort. Concerns about the difficulty of mastering GIS compel public school teachers to register for workshops to fill the knowledge gap.

5. Discussion and conclusion

This study provides evidence to support the position that, in offering GIS training, the efforts of the MOE and NTU are effective in encouraging teachers to become active adopters. But the cultivation and consolidation of teachers' capability to use GIS in imparting geography remains an important task for the MOE and NTU in the years to come because respondents are still more prone to teaching about, rather than with GIS as a whole.

In this concluding section, we aim to elaborate a bit more on why the NTU's in-service training is working. The main reason, we argue, is that the workshop is not merely about introducing GIS. There is also emphasis on encouraging teachers to think about how they can make use of GIS in their lectures. The workshops direct teachers to developing technological pegagogical content knowledge (TPACK) which cannot be found in standard university courses.

TPACK is a concept which has been increasingly debated among scholars working on the nexus between education and technology (Niess, 2005; Cox and Graham, 2009; Loveless, 2011; Avalos, 2011; Chai et al., 2013). The concept points out the complexity of the interplay of technology, pedagogy and content in teachers' professional knowledge (Koehler et al.,

2007). Their interactions result in pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK). These interactions are often depicted in a Venn diagram (Figure 2).
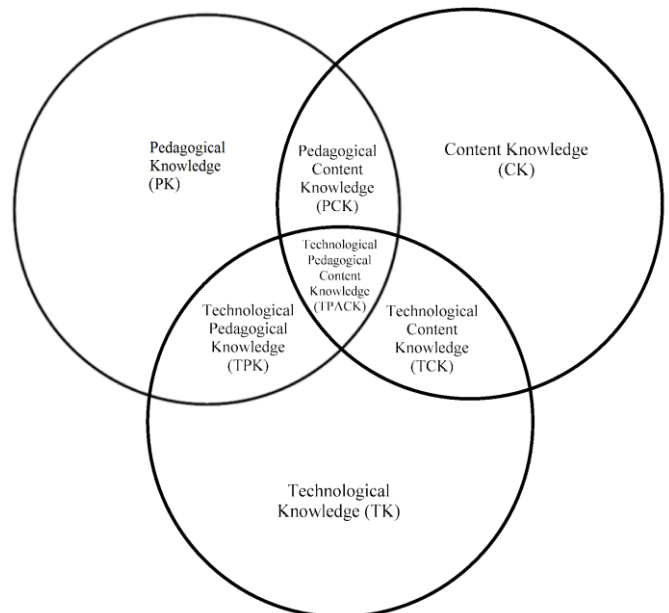

Figure 2. Technological pedagogical content knowledge (TPACK).
Source: adopted and redrawn from Koehler et al., 2007.

The definitions of these knowledge domains are not without critiques and debates. However, it is broadly understood that PCK refers to teachers' knowledge to represent content knowledge and adopt pedagogical strategies to make their lectures more comprehensible for students without the influence of technologies. TCK, TPK, and TPACK, differently, are knowledge domains related to technologies. TCK is the knowledge about how to employ technology to represent the content knowledge without considering its teaching. TPK refers to knowledge of the general pedagogical activities that a teacher can engage in using technologies. Lastly, TPACK is the knowledge about using technologies to teach, represent, and facilitate knowledge creation of specific subject content (Cox and Graham, 2009; Loveless, 2011; Chai et al., 2013).

Although TPACK appears to be an interesting framework, scholars have raised concerns about the occasional fuzziness of the actual constructs of these "knowledge domains" (Cox and Graham, 2009). Currently, exploratory factor analysis does not appear to support all these domains, either (Voogt et al., 2013). We do not intend to join the debate over the actual definitions of TPACK in this paper. Rather, we regard these concepts as orientation that can guide us when understanding teachers' development of professional capacity and knowledge (Voogt et al., 2013). As Kersi et al. (2013) argue, teachers' professional development should embrace TPACK. A stand-alone course focusing on training GIS skills and knowledge (i.e., TK) is not useful. Rather, the training should lead teachers to understand the intersections among GIS (TK), geography (CK) as well as how to apply GIS in education (PK).

The fact that the NTU's in-service training is designed in the spirit of TPACK makes the workshops popular among teachers in the first place. The NTU has been organizing in-service training for seven years. Every year, there are on average 16 workshops available for geography teachers throughout Taiwan. The annual total numbers of participants are 640, which is nearly half of the 1,530 or so senior high school geography teachers in Taiwan.

It should be noted that most high school geography teachers in Taiwan learned about GIS in their undergraduate and/or postgraduate education prior to becoming teachers. However, they generally lack a full grasp of GIS and a clear idea of how to apply it in their lectures. In other words, secondary school geography teachers should have taken courses in GIS (TK), geography (CK) and pedagogy (PK) respectively during their university education. Yet since they did not have the opportunity to take courses that teach them how to integrate these three knowledge domains, most teachers find it hard to include GIS in their actual teaching. The NTU's workshop thus meets these teachers' immediate aims.

The idea behind the NTU's in-service training is to lead teachers to brainstorm and use their creativity to find the connections between GIS and their lectures. In most of the NTU's workshops, at the end of the training session, teachers are required to present a lesson plan that demonstrates the integration of GIS into lectures. This approach is believed to be most efficient and meaningful for developing teachers' TPACK (Spotts, 1999; Huang et al., 2011; Chien et al., 2012).

One of the teachers who has participated in the workshop, for instance, related that he has used free wares such as Google Earth to teach about the Hexi Corridor (also known as the Gansu Corridor) in China. Using the flight simulator of Google Earth (TK), he presented the oases, graben, and other geological landscapes along the Hexi Corridor (CK). This simulation invited students to join a discovery learning process in which they visually understand how oases and settlements develop along the northern edge of the Tibetan Plateau and why, for traders and the military, this route was a historically important section of the Northern Silk Road. Combined with problem-based learning, the teacher asked students to discuss in teams, critically analyzing why cities such as Wuwei, Zhangye, Jiuquan and Dunhuang were formed as well as why the Hexi Corridor came to be.

This teacher understands the conceptual power of using the simulation of Google Earth to facilitate his teaching of the Hexi Corridor. This is a positive example of how GIS in-service training has re-oriented teachers from traditional ways of teaching to education in the spirit of TPACK.

It should be noted as well that teachers can obtain large amounts of spatialized data during the training. In preparation for the GIS workshops, the NTU's team has turned large amount of tubular data into spatial data (e.g., agricultural data, electoral data). Teachers also get to learn how to turn tabular data into shapefile and further create maps during the training. According to the US National Research Council's (2006) recommendations for promoting GIS, one of the key tasks is to strengthen the teachers' capacity to spatialize nonspatial data. The NTU's efforts are in line with this international ambition.

Lastly, making GIS software "teacher friendly" in terms of ease of installation,

maintenance and use has also been noted by the US National Research Council (2006) as crucial for GIS integration in education. Professional GIS software is indeed too complicated for secondary school teacheres. The NTU's success hence also lies in helping teachers to use easy to operate free wares. This naturally broadens the accessibility of GIS to more learners and paves the way for cumulative learning. Once teachers feel comfortable with easier GIS software and develop interests in its advanced application, they can be more willing to try professional GIS software. With the current success in mind, the MOE and NTU should continue to generate good TPACK-oriented training models for geography teachers to develop professionally. The Taiwan experience should also serve as a good model for GIS promoters around the world to follow in the future.

Acknowledgements

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