Pedagogical Potential of a Web-Based GIS Application for Migration Data: A Preliminary Investigation in the Context of South Korea

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Abstract

This article examines the pedagogical potential of a Web-based GIS application, Population Migration Web Service (PMWS), in which students can examine population geography in an interactive and exploratory manner. This article introduces PMWS, a tailored, unique Internet GIS application that provides functions for visualizing spatial interaction data. The easy-to-use interface of PMWS enables users to interactively and intuitively explore migration data in the form of flow maps and to use local data. The results of the usability survey indicated that pre-service teachers (n = 33) believe that PMWS represents an alternative GIS tool that overcomes the obstacles of desktop GIS in secondary education.

Key Words: *Population Migration Web Service (PMWS), web-based GIS, geovisualization, local data*

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Introduction

Researchers have noted the pedagogical potential of GIS (geographic information systems) and have tried to incorporate it into the classroom. The adoption of GIS into secondary education, however, has not been widespread (Baker and Bednarz 2003; Kerski 2003; Bednarz and Bednarz 2008; Baker, Palmer, and Kerski 2009). The complexity of desktop GIS has been one of the main reasons preventing teachers from incorporating GIS into the classroom. Because desktop GIS has been developed mainly to support professional research, it involves too many functions that go beyond the need of K–12 education. Teachers and students are not willing to spend considerable time to master GIS software, especially under the circumstances in which standardized tests are emphasized (Milson *et al.* 2005; Bodzin and Anastasio 2006; Milson and Earle 2007; Nielsen, Oberle, and Sugumaran 2011). These days, students are familiar with the use of technology, but they are also easily frustrated when technology is not intuitive (Nielsen, Oberle, and Sugumaran 2011). A key issue for the introduction of GIS into the classroom, therefore, is to decrease the learning curve to acquire GIS functionality (Henry and Semple 2012). Aware of this problem, Marsh, Golledge, and Battersby (2007) argued that educators should develop "minimal GIS" to substantiate the pedagogical potential of GIS. Scholars have noted the possibility of Web-based GIS because it is believed to provide a simplified and customized version of GIS. Internet GIS can reduce the complexity of the desktop GIS interface, thus it matches well with the notion of a minimal GIS.

This study investigates the possibility of Web-based GIS as an educational tool in the South Korean context. For this purpose, we introduce a Web-based GIS application: Population Migration Web Service (PMWS). This application is a customized GIS tool that provides key functions for exploring and visualizing migration data. Furthermore, we examine how pre-service teachers (college of education students) feel about the usability of PMWS. If teachers think that an educational tool is easy to use and useful for teaching, they are more likely to employ it (Hughes 2005). Considering the lack of research about the effectiveness of Web-based GIS activities on students' learning (Kerski 2008b), we believe this study represents a timely attempt to develop and examine the educational possibility of a Web-based GIS application.

Web-Based GIS in Education

Web-based GIS combines the power of the Internet and GIS. Internet GIS uses "a Web browser where geographic data are displayed as maps and graphs based on user-selected criteria" (Milson and Earle 2007, 227). Users have free access to Internet GIS. Moreover, Web-based GIS usually provides a simplified interface and up-to-date datasets (Milson and Earle 2007). Thus, educators pay attention to Internet GIS as an alternative to desktop GIS. Baker (2005, 46) argued that Web-based GIS is suitable for the secondary classroom in which teachers find it difficult to apply "time, commitment, and energy required of desktop GIS." Similarly, Milson and Earle (2007, 228) contended that Web-based GIS "has strong potential to be adopted for K–12 use to a much greater degree than has been enjoyed by desktop GIS." When a simplified Internet GIS is used, teachers and students can devote their time to developing spatial thinking skills rather than spending time to master techniques of using GIS (Doering and Veletsianos 2007).

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Research has reported successful implementation of Web-based GIS in the classroom. Bodzin and Anastasio (2006) developed an inquiry-based Web GIS module. In their study, students investigated real-world environmental problems through the aid of Web-based GIS. GIS enabled participants to effectively deal with a wide range of watershed data, such as better understanding of human impacts on water quality. In conducting research with GIS, students learned how to think spatially as scientists do. Milson and Earle (2007) reported that Internet-based GIS was successfully employed in secondary education. The researchers asked students to present their opinions concerning pressing issues in Africa, such as HIV/AIDS, famine, malnutrition, civil wars, and violence, as a representative of the African Union. In order to present their opinions persuasively, students visualized information using an Internet GIS. In this process students enjoyed GIS-based activities because they felt that they had expanded freedom in learning processes. Clark, Monk, and Yool (2007) found that in a Web-based GIS course students could control their learning pace, enabling them to spend the time needed to practice hands-on lab exercises. The students in the Web-based GIS course scored higher on lab sessions than those in a traditional GIS course. This finding deserves attention because research found that hands-on lab sessions play an important role in enhancing students' spatial thinking skills (Lee and Bednarz 2009; Kim 2011). Scholars recently also have noted the benefits of using digital globes such as Google Earth and ESRI's ArcGIS Explorer, which are a kind of Web-based GIS, in enhancing the development of spatial thinking (Kerski 2008a; Schultz, Kerski, and Patterson 2008).

To summarize, educators believe that Web-based GIS can increase the introduction of GIS into secondary education. Web-based GIS with an easy interface provides a minimal version of desktop GIS without requiring expensive hardware and software. Hence, teachers are more likely to use Web-based GIS in the classroom and it would play a critical role in realizing the pedagogical potential of GIS.

Population Migration Web Service (PMWS)

This section describes a Web-based GIS application, Population Migration Web Service (PMWS), and introduces its user interface.[1] PMWS is a tailored GIS application whose purpose is to interactively visualize and disseminate migration data. The audiences include those ranging from professionals making spatial decisions synthesizing diverse information to novices such as students studying concepts, principles, and practices regarding migration phenomena. When developing PMWS, we considered its educational application. In K–12 educational settings, researchers recommend reducing the functionalities of off-the-shelf desktop GIS because it decreases the learning curve and, therefore, does not intimidate learners (Henry and Semple 2012). Although topics regarding migration occupy an important part of geography education, no tailored Web GIS tool to examine these topics exists (Lee *et al.* 2008). We believe that PMWS could be a solution to address this problem.

Development of PMWS

Migration statistics provide useful information to understand spatial interaction between regions and their socioeconomic situations. Services to investigate and analyze migration statistics, however, have been limited because of the complexity of the data structure (i.e., *n*-squared geographical movements). In addition, flow mapping, which is one of the most effective methods to explore and visualize spatial interaction, has yet to be fully supported by current GIS applications (Kim and Lee 2012). On the other hand, recent developments in Web GIS technologies have enhanced "the open use of GIS in 1) spatial data access and dissemination, 2) spatial data exploration and geovisualization, and 3) spatial data processing, analysis, and modeling" (Dragićević 2004, 80). Given this, it is valuable to develop a Web-based GIS application for spatially exploring and visualizing migration statistics with flow maps as well as choropleth maps. PMWS was developed using C# in Microsoft Visual Studio 2005 as a programming language. We utilized ESRI ArcGIS server 9.3 as a GIS server engine and used Oracle 10g to manage migration statistics and relevant spatial data.

Interface of PMWS

There are several important features in the interface of PMWS (Kim and Lee 2012). First, the interface emphasizes exploratory visualization of migration statistics. Users can control the range of attributes, set spatial extent and scale to be mapped, and identify attribute values of specific features. In PMWS, users can select three different spatial scales: (1) level 1—Si (metropolitan cities) – Do (provinces); (2) level 2—Si (cities) – Gun (counties) – Gu (wards); and (3) level 3—Eup (towns) – Myeon (townships) – Dong (neighborhoods). In particular, as PMWS visualizes flows satisfying a user-defined threshold quantity, it is possible to effectively reduce the visual cluttering problem of flow maps without losing main flow patterns. The visual cluttering problem is a main drawback of flow mapping, resulting from the fact that $n(n\text{-}1)$ flow lines are visualized (Tobler 1987; Kim *et al.* 2012). Too many lines hinder effective interpretations of the visualized information. Second, the interface provides rich auxiliary information such as inset map, legend, explanation about variables, and relevant statistics. This function provides sufficient information for users to understand and explore visualized maps. Third, the interface is specialized and customized to deal with migration statistics. Users can make choropleth and flow maps by simply selecting year, spatial extent and scale, variable, classification method, number of classes, and color scheme. Users, therefore, can easily use PMWS without learning general functionalities of desktop GIS software.

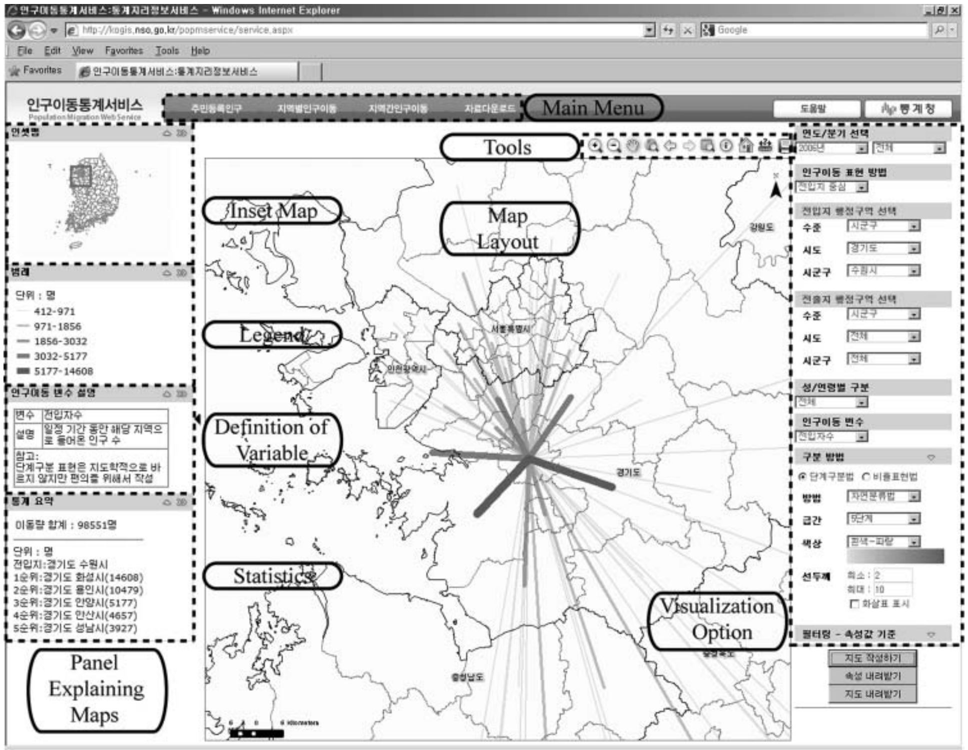

Figure 1. Graphic user interface (GUI) of PMWS.

Figure 1 shows the graphic user interface (GUI) of PMWS. Map layout is positioned in the center of a browser. The main menu and tools are found on the top. The panel to change visualization options is on the right side. Finally, panels explaining visualized maps such as inset map, legend, variable definition, and statistics are located on the left side.

Using PMWS, it is possible to make two kinds of thematic maps: (1) choropleth maps aggregated by areal unit and (2) flow maps between areal units. Figures 2–5 show sample maps created by PMWS. Figure 2 visualizes demographic effectiveness of migration by Dong (level 3, the most detailed scale) in Seoul. The demographic effectiveness is the ratio of net-migrants to total migrants and reveals the effect of migration on population change. In this map, the attribute values were manually classified. PMWS enables users to select classification methods such as manual, natural breaks, equal interval, and quantile methods. Figure 3 presents flow lines belonging to only top 10 percent gross-migration between Gus (level 2, intermediate scale) of Seoul. Figure 4 expresses out-migration from Seoul (level 1, the coarsest scale) to Si-Gun (level 2) of Gyeonggi-Do. This map demonstrates that it is possible to visualize migration between different spatial scales using PMWS. Figure 5 shows in-migration to Gangnam-Gu from the other Gus in Seoul. Figures 4 and 5 are flow maps visualizing migration related to a specific region.

STRENGTH OF PMWS

Unique Web-Based GIS Tool to Visualize Migration

PMWS represents a unique Web-based application to visualize migration in a GIS environment (Lee *et al.* 2008). Since migration data inevitably include data as dyad, the data structure is unique and more complex than that of other spatial phenomena, such as births and deaths, which occur in fixed places (Peters and Larkin 2008). This complexity of migration data makes it difficult to visualize flow patterns. Using PMWS, however, students can visualize and explore flow patterns at any scale.

The visualization of population migration enables students to effectively understand important geographic topics. For example, a suburbanization process usually entails the migration of residents from a central city to its surrounding suburbs, which can be examined using flow maps; the net-migration rate from an origin to destinations would be negative. A flow map visualizing this pattern shows outgoing arrows from an origin city to destinations, with the size of the arrows changing according to the magnitude of migration. We believe that flow maps best enable students to visualize migration between origin and destination. Utilizing flow maps in this case is not only intuitive, but also cartographically appropriate (Kim *et al.* 2012). PMWS is a unique Internet-GIS tool that supports this kind of visualization and analysis. In addition, PMWS provides data ranging from 1996 to 2011 (the most recent data at the time of writing this article),[2] thus students can examine the change of migration on a yearly basis.

User-Friendly Interface Supporting Exploratory Geovisualization

PMWS is a user-friendly mapping tool. Unlike desktop GIS, students easily understand how to produce maps using PMWS. This assertion is supported by the results of the usability survey discussed later. Therefore, students are unlikely to fall into a pitfall of "buttonology" in which GIS users passively follow technical steps to achieve a specified purpose (Marsh, Golledge, and Battersby 2007).

Employing the user-friendly interface of PMWS, students can take advantage of the power of geovisualization. Geovisualization emphasizes the exploratory nature of maps and interaction between maps and users (MacEachren and Kraak 1997). According to Kraak (2009, 468):

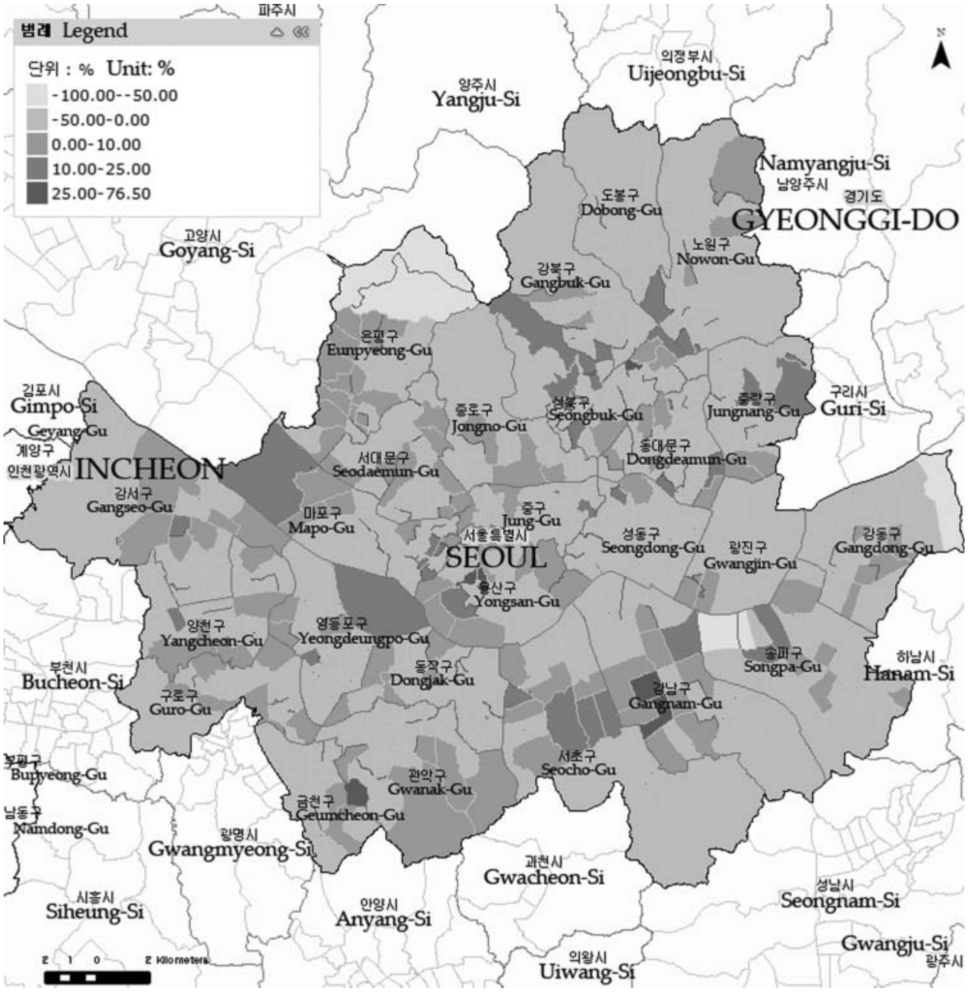

Figure 2. Demographic effectiveness of migration by Dong in Seoul (2006). (Sample map made by using PMWS.)

> Although it has to be realized that the traditional role of a map to "present" is still very much valid, today's challenge is to see the map as a flexible interface to geospatial data, since it offers interaction with the data behind the visual representation. The interactive and dynamic environments in which maps are used, often in combination with other graphic representations, encourage exploration. As such they are used to stimulate (visual) thinking about geospatial patterns, relationships, and trends.

By actively interacting with data and relevant maps in the PMWS environment, students can discover patterns and hidden meanings of migration data. Students can modify the way maps are visualized by changing options such as classification method, number of classes, color scheme, or line width. Students can perform exploratory spatial data analysis (ESDA) as professional researchers do (Bodzin and Anastasio 2006). ESDA is one of the most powerful advantages geospatial technologies provide in educational settings (Doering and Veletsianos 2007; Schultz, Kerski, and Patterson 2008).

The exploratory nature of PMWS helps students develop critical spatial thinking. Critical spatial thinkers do not passively accept provided data or problems (National Research Council 2006; Milson and Alibrandi 2008). They know that even the same dataset can be represented differently depending on the data class and scale selected by the cartographer (Kim 2011). As previously noted, PMWS allows students to change map design options in order to produce a map of their own. With these supporting functionalities, students can examine whether their maps reasonably support their argument or explanation and whether different representations could lead to different conclusions. These exercises are important learning activities that should be emphasized to develop critical spatial thinking skills, crucial to deal with spatial information and perform complex spatial tasks (Goodchild and Janelle 2010).

Use of Local Data

PMWS provides students with preprocessed local data. When PMWS is employed, students can use the data of their local areas wherever a school is located. PMWS is connected to the database provided by Statistics Korea, the census bureau of South Korea; it provides reliable datasets in a wide range of scales. This is an important support in education because research has found that using local data in GIS-based activities makes students actively participate in learning (Keiper 1999; Liu *et al.* 2010). Students show natural curiosity about their local areas when geospatial technologies are incorporated (Doering and Veletsianos 2007). Audet and Abegg (1996) argued that the use of local data is critical to successfully implement GIS into secondary education. Keiper (1999, 56) said:

> A strength of GIS is its ability to use the familiar, local data from the students' neighborhoods. These local data, used in conjunction with an authentic problem,

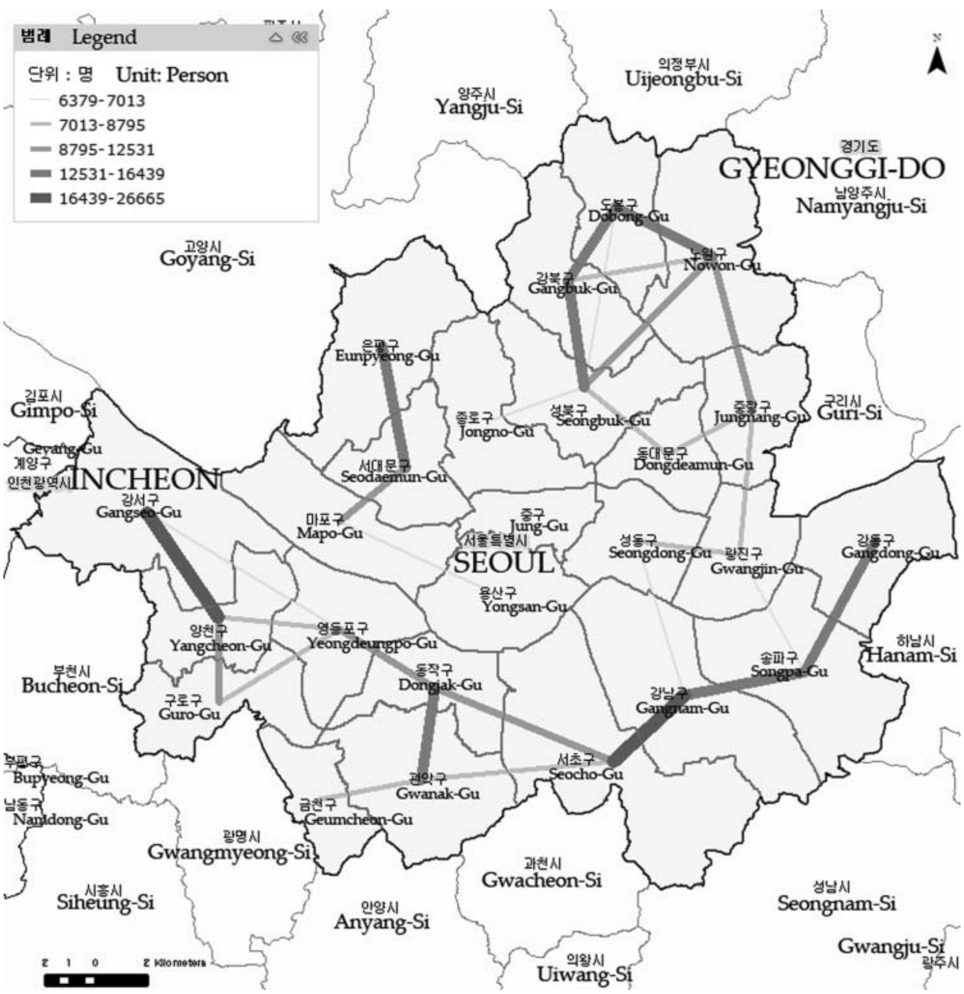

Figure 3. Gross-migration between Gus in Seoul (2006). (Sample map made by using PMWS.)

> give the student the powerful motivation of using the familiar for a valuable, real purpose.

Kolvoord (2008) reported successful projects in which high school students used GIS to investigate local issues, such as sorting out local transportation networks and exploring local watersheds. Students in this study were intrigued by the fact that they used familiar local data. Students realized how real-world phenomena around them could be connected to GIS-based learning by visualizing and interpreting spatial patterns. Shin (2006) found that the incorporation of local data from students' surroundings helped them understand geography from their life contexts. According to Henry and Semple (2012), teachers responded positively toward GIS activities in which they collected local data to investigate the relationship between land use and water quality.

With the aid of PMWS, teachers can take students' everyday experiences into consideration when designing their lessons. Recall the example regarding the suburbanization process described earlier. A teacher discussing this topic could incorporate local examples because PMWS provides data at different administrative scales across South Korea. Students can examine where people in their city are migrating to and from. This is a powerful strategy teachers can use to attract students' interest and help their geographic learning.

PMWS Usability Survey

We examined the usability of PMWS using the survey instrument (Table 1). The instrument is composed of six closed-ended questions investigating the subjects' opinions by means of a five-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, 5 = strongly agree) and one open-ended question asking the participants to evaluate PMWS as a teaching and learning tool.

Pre-service teachers in South Korea provided their opinions. As a preliminary investigation, pre-service teachers were selected as participants because they have characteristics of both students and teachers. As they graduated from high school a few years ago, it is possible to assess PMWS from students' views. In addition, they are currently being trained as teachers; the participants have a wide range of teaching-related experience such as developing instructional materials and performing teaching practice. Thus, they have the ability to evaluate PMWS from teachers' perspectives. Further research, however, with in-service teachers and students at secondary education should be conducted to confirm the results reported here.

Participants

Pre-service teachers at three universities in South Korea participated in the survey. The participants were geography education majors. In total, thirty-three participants completed the survey. Thirteen males and twenty females participated. In South Korea, to become a geography teacher in public schools, two steps are required: obtaining eligibility and passing a teacher certification exam (Kim and Lee 2011). The College of Education includes the department of geography education that specializes in training future geography teachers. Once pre-service teachers graduate,

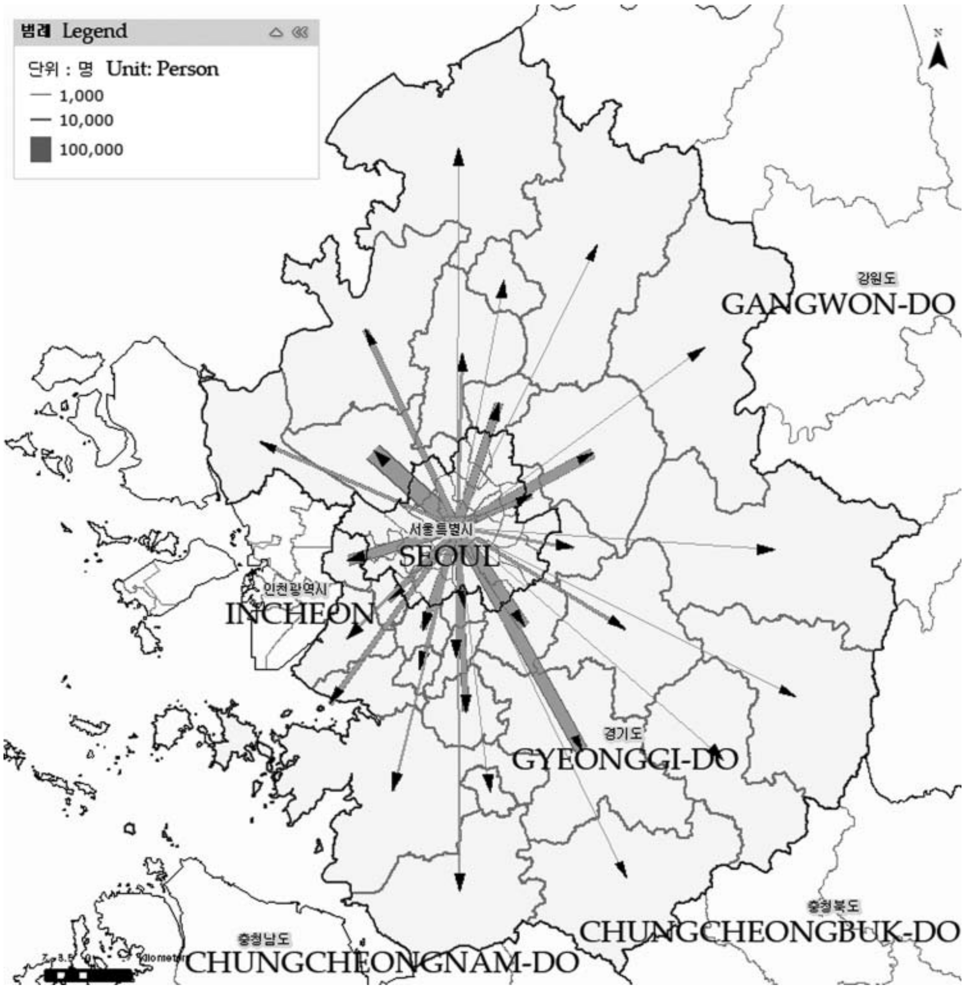

Figure 4. Out-migration from Seoul to Si-Gun of Gyeonggi-Do (2006). (Sample map made by using PMWS.)

they are eligible for a teacher certification exam. The participants in this study were sophomores and juniors. They took one or no GIS-related course.

Settings

The current status of the incorporation of GIS into secondary education in South Korea is not different from that of most other countries. Teachers in South Korea acknowledge the potential of GIS as a teaching tool, but they worry about obstacles such as hardware, software, and complexity of desktop GIS (Kim and Lee 2011). Since the geography curriculum in South Korea requires teachers to introduce GIS, pre-service teachers are interested in how to effectively teach GIS to students (Kim, Bednarz, and Lee 2011).

Procedures

We introduced PMWS and demonstrated how to use it to participants. Then, the participants had time to individually familiarize themselves with the application. Because the participants were given a week to play with PMWS, we believe they had sufficient time to examine the platform. The participants were asked to consider whether PMWS could work as an effective educational tool in K–12 education. Each participant may have spent a different amount of time to play with PMWS. We did not intend to measure how quickly pre-service teachers might learn the PMWS interface but aimed to give participants sufficient time to master PMWS and to consider educational uses. The participants believed that they had enough time to evaluate PMWS. After one week from the introduction of PMWS, the participants completed the usability survey.

Findings

Overall, the participants responded positively to the usability of PMWS (Table 1). Pre-service teachers answered that they interactively explored migration patterns with PMWS (item #2, mean score = 4.1) and were inclined to incorporate the application into their teaching (item #4, mean score = 4.2). This response might be related to the participants' positive evaluations that PMWS could promote students' geographic learning (item #5, mean score = 4.0).

Most participants (76 percent) replied that they easily understood the user interface of PMWS (item #1, mean score = 3.9). Some participants responded that it was not easy to master the PMWS interface at the beginning, but they became familiar with it after some practice. The response to item #3 (mean score = 3.8) could be understood in relation to that of item #1. Participants may have predicted the level of difficulty that students would encounter based on their experience in learning to use PMWS.

The mean score of item #6 asking about strategies to teach with PMWS was 3.6. This relatively low score, we believe, does not indicate that PMWS is an inadequate tool for education but rather that the pre-service teachers had not had sufficient opportunities to learn and practice how to teach with GIS. Even though further empirical research is required, GIS courses in South Korea need more attention on teaching with GIS (Kim and Lee 2011). The finding

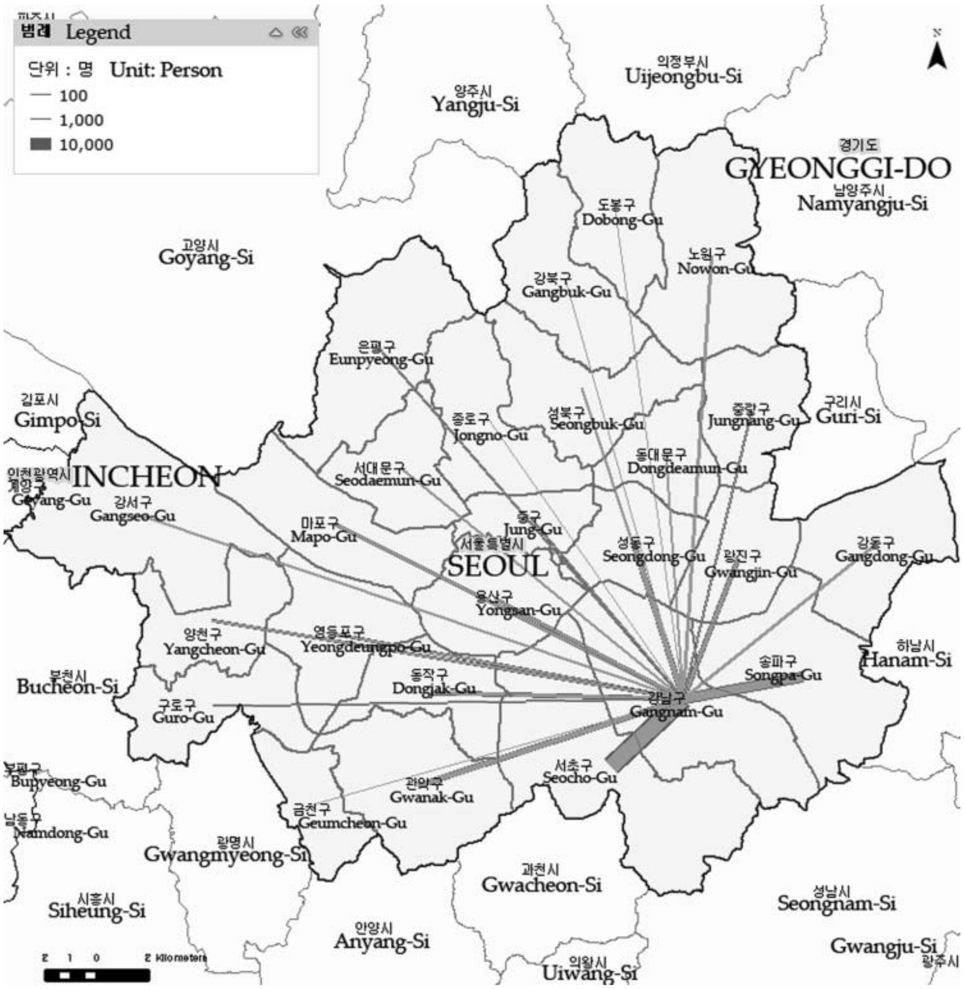

Figure 5. In-migration to Gangnam-Gu from other Gus of Seoul (2006). (Sample map made by using PMWS.)

from item #6 indicates that pre-service and professional development programs that promote teachers' capability to develop GIS-based activities from educational perspectives are necessary. Even though Web-based GIS reduces the learning curve to master the GIS functionality, this does not mean that teachers' expertise to use GIS educationally is unnecessary. To successfully introduce geospatial technologies into secondary education, teachers should possess technological pedagogical content knowledge, a capability to understand the complex interrelationships between and among geography content knowledge, pedagogical knowledge, and technology knowledge (Bednarz and Bednarz 2008; Mishra and Koehler 2006). To teach population geography with PMWS, teachers do not need to spend much time to learn the interface, but they should possess expertise to create effective lesson plans.

We investigated the participants' opinions in depth through the responses of the open-ended question. The major opinion was that students at the secondary education level would be interested in using PMWS because it can support activities in which students examine spatial information interactively and produce maps by themselves. The following excerpts present a few responses from the participants.

> PMWS seems to be useful for education because it is easy to use and to visualize information. In addition, PMWS has high accessibility because it is a Web-based application. Students will be interested in the application because they can create familiar examples, for instance, migration differences between their city and those of their relatives.

> I would like to incorporate PMWS in my class. PMWS enables students to understand abstract geographic concepts from real-world contexts. Students would be motivated to use it because they can grasp migration with visual aids and statistics.

> Until now, textbooks have introduced the topic of migration with static visual pictures, but the use of PMWS overcomes this limitation. Students can examine migration patterns by themselves, so they would like these activities. Students could know that different maps are produced by changing options PMWS offers. I think this experience helps develop students' ability to analyze spatial representations, such as maps, diagrams, and tables.

> Activities using PMWS would stimulate students' interest. Since they are not the type of activities students have exercised, students are likely to be motivated. PMWS-produced maps could be used as visual materials to facilitate students' understanding.

Several pre-service teachers recommended instructional strategies to introduce PMWS into the classroom.

Table 1. Participants' responses to the closed-ended questions.

	Response Distribution (n = 33)					
Item	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Mean Score
1. I easily understood how to use PMWS.	—	1 (3%)	7 (21%)	18 (55%)	7 (21%)	3.9
2. I explored migration patterns interactively using PMWS.	—	—	5 (15%)	21 (64%)	7 (21%)	4.1
3. I think K–12 students could use PMWS easily, so it can be introduced into the classroom.	—	1 (3%)	8 (24%)	19 (58%)	5 (15%)	3.8
4. I would like to incorporate PMWS in my class.	—	1 (3%)	4 (12%)	17 (52%)	11 (33%)	4.2
5. I think the incorporation of PMWS would be beneficial in enhancing students' geographic learning.	—	—	9 (27%)	15 (46%)	9 (27%)	4.0
6. I can think of instructional strategies or examples to apply PMWS for my teaching.	—	3 (10%)	10 (30%)	16 (48%)	4 (12%)	3.6

> I think PMWS can be utilized to explain contents regarding migration. In particular, topics such as suburbanization and uneven development of South Korea fit well with the use of PMWS. By showing maps of migration interactively, students could connect concepts learned in class to the real-world. It is also interesting that PMWS provides functions to visualize migration according to gender and age. This capability helps students effectively understand differences in migration patterns by these variables.

> I believe using group activities is an appropriate strategy to incorporate PMWS into the classroom. Students as a team select a region and investigate migration. In doing so, they need to delve into reasons of the migration. Finally, students could present their research in class, sharing information and opinions with classmates.

Some participants suggested cautionary comments. One of them includes the necessity of the explanation of relevant concepts in using PMWS as the following excerpt shows:

> Students should have an understanding of terms such as net-migration and gross-migration. PMWS provides definitions of these terms, but some students could have difficulty in understanding these concepts. Therefore, it would be more effective to use PMWS with conceptual explanation of relevant concepts.

Considering the complexity of migration data and relevant concepts, these responses are not surprising. We believe that in using PMWS, students' understanding of concepts regarding migration such as in-migration and out-migration is a prerequisite. Students also would need to grasp cartographical concepts of classification methods, such as natural breaks, equal interval, and quantile.

Even though many participants thought the interface of PMWS was not difficult to master, some pre-service teachers responded that it was not easy for them to understand how to use the application at the beginning. These participants recommended that teachers should demonstrate how to use PMWS prior to students' activities.

> At first, it was not easy for me to understand functions of each button. After I practiced several times, however, I could use it without difficulties. This may also be the case for middle or high school students. Once students become familiar themselves with the interface of PMWS, the application may help them understand migration phenomena. I think it would be better if a teacher shows how to use the application before students begin to use it. Or the application could be used only by a teacher to demonstrate some cases.

To summarize, the results of the usability survey suggest that PMWS is a recommendable educational tool. The participants could understand the interface relatively easily and, furthermore, they used the application to investigate migration interactively. Pre-service teachers wanted to employ it in their teaching. However, caution also needs be exercised. Some pre-service teachers responded that it took time for them to master the application, and the meaning of relevant concepts should be taught prior to the use of the application.

CONCLUSION

This study outlined the development of a Web-based GIS application, Population Migration Web Service (PMWS). This application is a tailored Internet GIS platform that enables users to investigate patterns of migration in Web environment. PMWS is a unique Web-based GIS that provides functions to visualize migration in the form of flow maps. As PMWS provides an easy interface supporting exploratory geovisualization, the learning curve might be reduced. PMWS also provides local data across South Korea, so it can be used to create local examples to motivate learners.

After developing PMWS, we administered the usability survey. Pre-service teachers believed that PMWS could be an effective educational tool. Even though prior research has found that GIS learning is beneficial in enhancing students' spatial thinking, desktop GIS has not been widely incorporated into the classroom. To address this problem, educators have argued that Web-based GIS could provide an alternative strategy. The development of PMWS is an effort to respond to this call. The use of Web-based GIS is suitable particularly in the South Korean context because the country has the fastest Internet connection speed in the world (Whitney 2010), therefore, the limited bandwidth problem is not an issue. Reliable Internet access is guaranteed across schools in South Korea.

In order to fully demonstrate the pedagogical potential of PMWS, further research examining the effectiveness of the application on improving students' geographic learning or spatial thinking skills should be undertaken. This study represents an initial step to explore the pedagogical potential of PMWS. The development of activities using PMWS and the implementation of them into the classroom should follow. Before rushing into the widespread incorporation of PMWS into the classroom, however, it was necessary to investigate whether the pursuit of further research regarding the use of PMWS for education is warranted. Our future research will develop PMWS-based exercise and examine its educational effects. Participants also will be extended to include in-service teachers and students at the secondary educational level. Finally, we are refining the interface of PMWS to make it more intuitive for users. Through these endeavors, PMWS could play a critical role in realizing the power of GIS in education.

NOTES

1. PMWS is available at http://kogis.nso.go.kr/popmservice/service.aspx (accessed December 17, 2012).
2. PMWS is updatable with new data making time series analyses possible. Because few boundary changes, especially at the levels 1 and 2, have occurred, temporal inconsistency in spatial units is negligible. However, we recognize that a full-fledged time series analysis at a finer level requires a sophisticated estimation technique to obtain a completely comparable data set across years (Feng and Boyle 2010).

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