

EXAMINING THE EDUCATIVE PRACTICE WITH GEOGRAPHIC INFORMATION SYSTEMS THROUGH THE TEACHERS' PERSPECTIVE

Gustavo Nieto¹, Alexander Siegmund²

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ABSTRACT:

With the objective of analyzing the frequency of use of Geographic Information Systems (GIS) in secondary education's Geography, the kind of programs used, the topics treated and the factors that will predict the teacher's use of these tools; an online survey was conducted in course 2014-2015 with a sample of 146 teachers. The results showed a sporadic use of Web GIS, self-taught instruction, and that GIS are used to deal with complex spatial problems. As a result it is necessary to simplify the use of GIS, modifying the curriculum and adapting GIS software to increase its use.

KEYWORDS:

Geographic information systems, geography education, Germany, teaching problems, statistical models.

¹ *Department of Education – Didactics of History, Geography and other Social Sciences (DHI-GECS), University of Barcelona, Barcelona, Spain. Pg. de la Vall d'Hebron 171 08035 Barcelona, Llevant Building, email: gnieto@ub.edu. ORCID: 0000-0002-8199-7898*

² *Department of Geography – Research Group for Earth Observation ("geo), Heidelberg University of Education & Heidelberg Center for the Environment (HCE) / Institute for Geography, Heidelberg University, Heidelberg, Germany. Czernyring 22 / 11-12 69115 Heidelberg, email: siegmund@ph-heidelberg.de*

RESUMEN:

Con el objetivo de analizar la frecuencia de uso de los Sistemas de Información Geográfica (SIG) en la Geografía de la educación secundaria, los temas tratados y los factores que afectan a estas herramientas, se realizó una encuesta online en el curso 2014-2015 con una muestra de 146 profesores. Los resultados mostraron un uso esporádico de los Web SIG, una formación autodidacta y que los SIG se utilizan para tratar problemas espaciales complejos. Como resultado, es necesario simplificar el uso de los SIG educativos, modificar el plan de estudios y adaptar el software para aumentar su uso.

PALABRAS CLAVE:

Sistemas de información geográfica, educación en geografía, Alemania, problemas de enseñanza, modelos estadísticos.

RÉSUMÉ:

Afin d'analyser la fréquence d'utilisation des Systèmes d'Information Géographique (SIG) dans la géographie de l'enseignement secondaire, les sujets abordés et les facteurs qui affectent ces outils, un sondage en ligne a été réalisé au cours de l'année académique 2014-2015 avec un échantillon de 146 enseignants. Les résultats ont montré une utilisation sporadique du Web SIG, une formation autodidacte et que les SIG sont utilisés pour traiter des problèmes spatiaux complexes. Par conséquent, il est nécessaire de simplifier l'utilisation du SIG éducatif, de modifier le programme d'études et d'adapter le logiciel pour en accroître l'utilisation.

MOTS CLÉS:

Systèmes d'information géographique, éducation en géographie, Allemagne, problèmes d'enseignement, modèles statistiques.

1. INTRODUCTION

The 21st Century society demands different skills from those provided by the schools of the previous century. In our society there is an increasing importance of geotechnologies and therefore the introduction of Geographic Information Technologies (GIT) in the classroom has to become a reality. Geo-data and apps like Google Maps, Google Earth, GPS, or travel blogs are of common usage today and they need to be common in secondary education too (Nieto, 2014). For that, we need to change contents and methodology in Geography classrooms using more technologies related to space, and information management: Geographic Information Systems (GIS). GIS have been very successful in the professional and scientific world, as well as in the administration

and, at the same time, are very useful tools for making critical and reasoned decisions in a democratic society (Kerski, 2008; Nieto, 2016b).

GIS are an integrated set of computer, human and procedural elements designed for the collection, storage, manipulation, deployment and analysis of spatial data and its related attributes (Lázaro and González, 2005; Lam, Lai, and Wong, 2009; Kerski, Demirci, and Milson, 2013). GIS are typically used to solve complex planning and management problems in our environment, helping government and business decision-makers, or discovering patterns for scientific studies.

In the last two decades GIS began to be recognized as facilitators of research learning, the constructivist didactic approach and problem-based learning (PBL) in secondary education, and expanded into schools across a multitude of countries (Kerski, 2008; Milson, Demirci, and Kerski, 2012; Kerski, Demirci, and Milson, 2013; Viehrig, 2014; Schubbe, 2014). The GIS seem to improve, within social and political aspects, the geographic and citizen awareness (Goodchild, 2007).

But in spite of the global interest in the research of educational GIS in the Geography classes, there is a global lack of real knowledge about didactics with GIS and a poor development of the educational theory around them (Baker et al., 2012; Baker and Bednarz, 2003; Siegmund, Volz, and Viehrig, 2007; Viehrig, 2014). The evidence regarding the educational advantages of GIS has little scientific evidence behind (Baker et al., 2014; Siegmund, Viehrig, and Volz, 2007) and thus we have to develop the causes that lead to the diffusion of GIS in education, detect the factors that affect it and probe the benefits they have in education. This educational role of the GIS needs to be defined based on methodical and empirical research in order to be able to demonstrate if they fulfill the reasons put forward by the research community.

For this reason we piloted an observation of the educational practice of GIS among Geography teachers in the German state of Baden-Württemberg where the GIS is present in the educational curriculum since 2001 in its secondary school upper itinerary, the *Gymnasium* (Viehrig and Siegmund, 2012; Höhnle, Mehren, and Schubert, 2015).

1.1. Theoretical framework

In order to define and explain the causes that lead to the diffusion of GIS in education and to detect these factors more easily we selected three models used in economics and computer science: Technology Acceptation Model, User Acceptance of Information Technology model and the Theory of Diffusion of Innovations (Davis, 1989; Venkatesh et al., 2003; Rogers, 2003; Pérez, 2005).

The first two focus on the perception of utility and the perception of ease of use as the main factors in the diffusion of innovations. These in turn are broken down into the

advantages and yield they produce, the social influence they cause, the effort required to use them and the conditions that allow their implementation: the ability to test them and the compatibility with the personal rhythm of life.

The third focuses on the types of users of innovations and their rate of adoption within the population, noting that the first types of users (innovators) focus on utility, while the transition towards the majority of the population (passing the 16%) needs a simplification of the technology through an external investment that adapts the innovation to the final users and their conditions.

Finally, we combined the previous proposed theories with previous studies on educational GIS (Kerski, Demirci, and Milson, 2013) to concretize the concepts to be developed in our research. The ease of use was represented by the main factors of GIS training, self-perceived skill with the tool and the existence of adapted software (Nieto, 2016a); also utility and advantages are expressed in the form of resolution of some didactic problem. The existence of a curriculum that defines the educational function of GIS has also been observed as an important factor in its dissemination (Nieto, 2016b).

1.2. Objectives

The objectives are linked to two hypotheses: In hypothesis A there are courses, topics, scales, tasks or GIS programs that are more used than others within educational GIS use in Geography. In the hypothesis B the training in GIS, the expertise with GIS, the availability of data and teaching materials, the time of private use of GIS, gender, age or professional experience influence the frequency of use of educational GIS in Geography.

On this paper, we want to focus on the following objectives developed from the previous hypothesis:

- (1) To quantify the frequency of use of GIS programs and in which Geography courses are used.
- (2) To categorize the use of topics and scales to teach Geography with GIS and in what courses is done.
- (3) To analyse if the GIS are used to deal with difficult Geography issues.
- (4) To relate the most relevant factors influencing the GIS use of the sample with its educational use and frequency.
- (5) To create a predictive model that forecasts the use of GIS as a teaching tool and its frequency of use and allows us to identify the variables that affect it.

2. RESEARCH METHODOLOGY

During the academic year 2014-2015 a survey was conducted to analyze the educational practice with GIS in the Geography of secondary education of the German state of Baden-Württemberg (BW). The survey consisted of an online self-administered questionnaire of 20 questions and a total of 50 variables after data cleansing.

The questionnaire included a presentation and was divided into four sections: a GIS knowledge test, didactic use of GIS, influence factors and personal data. The questions were of three types: conduct (9 questions), attitude (3 questions) and information (8 questions).

The population sample consisted of 146 *Gymnasium* teachers obtained from non-probabilistic methods of snowball and conglomerates. The sample size was not established until the end of the study, but the total of BW *Gymnasium* Geography teachers (N=3089) was theoretically accessible because we could contact all of them through the ways described below. The total teacher data was obtained asking directly to the *Statistisches Landesamt Baden-Württemberg* and *Ministerium für Kultus, Jugend und Sport Baden-Württemberg* via email. Although the final sample of 146 subjects is less than the necessary subjects to generalize the conclusions, the findings of the research are significant because they allow us to identify the main variables that intervene in didactic practice with GIS and reinforce both theoretical models and previous research. Also, the samples of previous studies tend to be smaller than ours (Audet and Paris, 1997; Johansson, 2003; Kinninburg, 2008; Lam et al., 2009; Demirci, 2009, 2013; Ateş, 2013).

A hyperlink or QR code was administered to the sample redirecting to a web application that managed the survey and stored the data on German servers. The application was active from June 9 to August 31 2015, with reminders on June 30, July 8 and July 15. Seven contact channels were used to present the link: the personal contacts of the authors, the members of the Society of Geography Teachers of Baden-Württemberg, the web page of the Research Group for Earth Observation (‘geo’) from Heidelberg Education University, the newsletter from the GIS-Station – Klaus-Tschira Centre of Competence for digital Geo-media, a poster with a QR code, an email with invitation send to 723 *Gymnasien* and, finally, an email to the people in charge of the subject of Geography of the *Gymnasien* section of the department of school and education of the four regional governments of BW.

The obtained data were transferred from the initial servers to the researchers' personal database and were treated with SPSS (Statistical Package for Social Sciences) version 22 and Microsoft Excel 2010 version 14. An initial descriptive analysis of the data was conducted before addressing to a more deep study. Among the techniques to address the relationships and differences between variables we used contingency tables (χ^2), correlation

indices (Pearson's r) and differences tests (Student-Fisher's t and ANOVA) (Pallant, 2010). In addition, nonparametric tests were used when non-normality cases were detected after applying the Kolmogorov-Smirnov-Lillefors and the Shapiro-Wilks tests.

The techniques used for explanatory and predictive analysis were multiple lineal and logistic models (Briones, 1996). The regressive models require estimating the parameters that compose them, validate and analyze their assumptions and verify their prediction (Solanas and Guàrdia, 2012). In order to verify the accuracy of the prediction we used the mean magnitude of relative error (MMRE) from Kitchenham et al. (2001).

Information about the topics used in the classrooms was refined, translated, categorized and finally classified into frequency tables and graphics. In order to codify the nominal type variables that emerged from open questions, groups had to be built on what was being repeated (Pallant, 2010), translating and standardizing responses. We had a large number of different themes with small nuances of difference between some and abundant use of synonyms; we initially grouped the themes into what we would call "subcategories" from repetitions and generalizations. We also created a higher level called "categories" from the UNESCO nomenclature (UNESCO, 1989) and "super-categories" corresponding to the classical division of Geography (Holt-Jensen, 2009): Physical Geography, Human Geography, Regional Geography and Techniques. 15 categories and 50 subcategories were obtained with the most common and the most difficult subjects.

The sample was questioned about what were the three most difficult topics they found in their Geography classes and what were the three more usual topics they used in their Geography classes using GIS, each three for each kind of GIS: Mobile, Web and Desktop. Additionally the topics were related to a scale of treatment. The main target of those questions was to establish parallelisms between the two groups and to respond to the question if GIS help to solve teaching problems and in which geographical scale is GIS more effective.

We used five categories in the treatment scale: local, regional, national, international and global from the standard educational geographic scales for Germany discussed in the document of Deutsche Gesellschaft für Geographie (2012) regarding geographic competencies. The language used by the sample was German and the resulting text was later translated and categorized for frequency processing.

2.1. Limits of the study

All research has limitations as a consequence of the methodology used. In our case we found that the sample needed to be larger and the sampling more systematic. This has meant that the results are not clearly generalizable and in the failure of several

assumptions in the models. We have also detected possible incidences of unknown variables in the models, which, on the other hand, may not be entirely efficient -although their prediction is good-, which leads to the conclusion that theoretical explanations are either missing nor certain variables were not adequately measured. Even so, the findings are significant because they allow us to identify the main variables that intervene in the didactic practice with GIS and reinforce both theoretical models and previous research. Regarding the territorial scale of the study, we chose a German federal state for diverse reasons (familiarity and proximity), but the main one is the presence of GIS in the curricula; then we present the state as an example for analysis.

3. RESULTS OF THE STUDY

The usage of GIS among *Gymnasium* Geography teachers during the academic year when the study was conducted (2014-2015) showed results of 49 “Yes” subjects (33.6%) and 97 “No” subjects (66.4%). So, most teachers have not used GIS in the academic year, but a not insignificant percentage did declare to have done so. The casual and sporadic use of the GIS among the teachers who use it is the norm, although there is an habitual use with very motivated subjects in high percentage that use the GIS within a great quantity of subjects of Geography.

As we can note in Table 1 the intensity of use of GIS was moderate in courses 11-13, and a very low use in courses 5-6; thus the greater the age the greater the probability of using GIS. There are three more or less clear blocks: very young students (10 to 11 years old), young students (12 to 15 years old) and students with high cognitive development (16 to 18 years old).

| Students' age | <i>Gymnasium</i> course | Percentage of use |
|---------------|-------------------------|-------------------|
| 16-18 | 11-13 | 31% |
| | 9-10 | 23% |
| 12-15 | 7-8 | 26,1% |
| | 5-6 | 4,9% |
| 10-11 | | |

TABLE N° 1. Percentage of GIS usage related to *Gymnasium* courses.

About the mentioned frequency of use we theoretically estimated that a value of more than 12 lessons per year would already be an intensive use and more than 24 would be an extremely high use. While the median and mode showed in Table 2 stand at 4.5 and 3.5

respectively, the arithmetic mean is 7.36 indicating the existence of very high values but meaning that teachers are far from an intensive GIS use in general. The great dispersion of values respect to centrality and the accumulation of values in the mode despite this dispersion suggests that extreme values do not accumulate in a few but are distributed among several individuals. The low frequencies of use of GIS would be between 1 and 3, the average frequencies between 4 and 7 and the higher ones in 8 or more reaching subjects with very high frequencies of use of GIS in the classroom (reaching 39 times per year).

An average frequency of 5 to 6 times suggest that a whole Geography teaching unit can be conducted using GIS as teachers take several lessons within a year using GIS. Also some teachers would use GIS to treat greater educative projects, more ambitious, or more than a teaching unit per year.

| | | Data | Data without outliers |
|---------|-------|------|-----------------------|
| N | Valid | 48 | 44 |
| | Lost | 98 | 102 |
| Mean | | 7.36 | 5.3 |
| Median | | 4.5 | 3.5 |
| Mode | | 3.5 | 3.5 |
| Minimum | | 1 | 1 |
| Maximum | | 39.5 | 17 |

TABLE N° 2. GIS frequency of use in the classrooms.

However, in order to carry out a more precise analysis it would be necessary to discard the extreme values that affect, above all, the measures of centrality. Within the data we found two very extreme values (37.5 and 39.5) and two outliers values for the sample (19 and 24). We can see that they approximate the theoretical values (12 and 24) mentioned above as very intensive uses.

Discarding these outlier values the statistical description in Table 2 gives us a better definition of the overall behavior of the sample. The mean is lower (5.3) and close to the median. Although there is still considerable dispersion towards high values, the distribution is much more normal and less biased towards the left. Within the sample the majority of users of educational GIS are distributed approximately normally around a value of 3.5 of annual uses, but we found highly motivated subjects (more than 8 annual uses) within 27% of GIS users.

If we look at the frequency of use from the specific programs the most frequent value, with difference, is the use between 2 and 5 times a year of GIS in Geography classes. Therefore, if we observe the data without outliers the results are lower, with about 4 uses per year meaning that most of the teachers show the GIS programs rather than conduct a whole teaching unit. Possibly they use GIS to support them explaining the subject and are not using GIS to teach.

Regarding the factors that influence this usage we identified some variables that are significantly important. On one side the *Teaching with GIS* is very influenced by *Didactic* ($t=5.14$, $p=0.000$) and *Technical* ($t=3.36$, $p=0.001$) *GIS training on its own account*, as well as by *GIS technical training as a teacher* ($t=3.04$, $p=0.003$) and the *Grade of knowledge in GIS* ($t=2.99$, $p=0.003$). The two technical formations mentioned complied with the Levene test, but not the other variables. Due to the infringement of parametric assumptions we used non-parametric test, as the z-test of Kolmogorov-Smirnov, to isolate the most relevant variables, and *Technical GIS training on its own account* ($z=2.18$, $p=0.000$) and *Didactic GIS training on its own account* ($z=2.44$, $p=0.000$) tested positive, reinforcing the previous parametric analysis. The *Frequency of GIS usage*, on the other hand, is significantly influenced by the *Private use of Desktop* ($r=0.697$; $p=0.000$) and *Web GIS* ($r=0.616$; $p=0.000$) as well as *Technical* ($r=0.420$, $p=0.003$) and *Didactic* ($r=0.456$, $p=0.001$) *GIS training on its own account*.

3.1. Successful GIS programs on education

In our survey we asked teachers in what courses they taught Geography and in which they used GIS together with the specific GIS programs they employed. We found in the sample a use of GIS fundamentally in higher courses, with some presence in the middle, and focused almost exclusively on the Web GIS, with a small presence of the Desktop GIS in advanced courses. As we can see in Figure 1 the percentages of use relegate courses 5-6 to a marginal position in the use of the GIS, leaving the 11-13 courses as the majority (55.17% of the declared total) and the rest as intermediate groups. The cognitive abilities of the students seem capital to allow teachers to use GIS at schools.

If we focus on the individual programs, in Figure 2 with the percentage of the total number of times used, we obtain a preference of the teachers for the Web GIS, namely Diercke WebGIS (22.41%) and WebGIS Schule (24.13%). The "Other Web GIS" section is also very important, consisting of several programs obtained by open response such as Klett GIS –with 9.05% of the total number of programs, in third position– followed by LMZ WB Geoportal (5.67%). The preference for using Web GIS as the preferred platform is clear with 76.71% of the programs used. Mobile GIS have marginal usage with 3.44% and Desktop GIS are only used 19.8% of the time. The easiness of use

and convenience of Web GIS seem to be the key factors: compared with the install requirements, database management and sophisticated tools of Desktop GIS or the lack of comfortable interface of Mobile GIS.

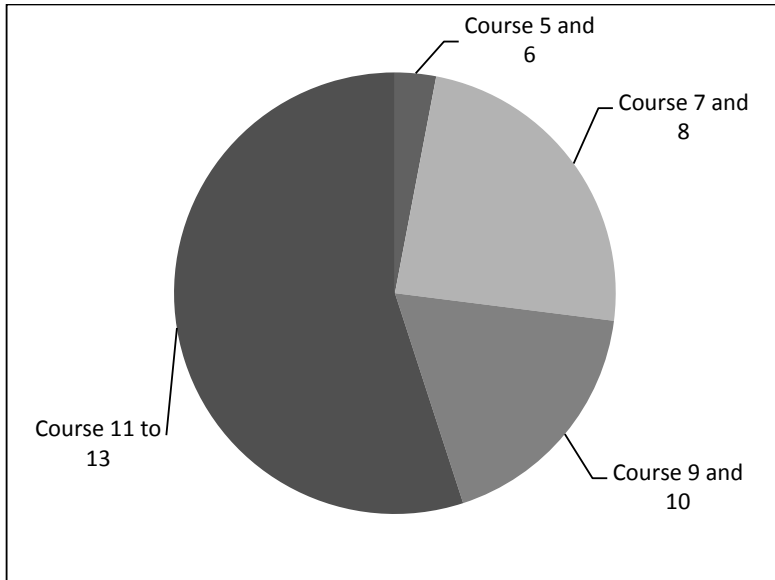


FIGURE N° 1. Use of GIS in *Gymnasium* courses.

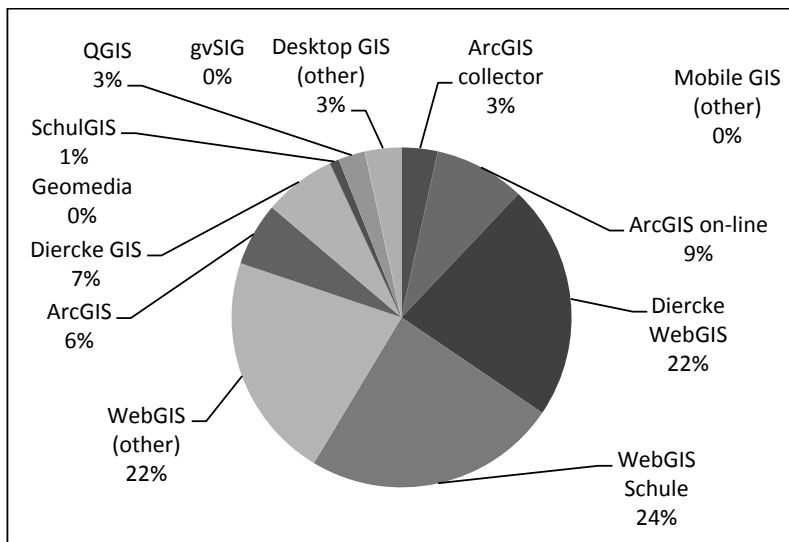


FIGURE N° 2. GIS programs used by teachers in *Gymnasium*

Within the use by type of GIS in each range of courses in Figure 3 we can see that although the Web GIS is still the most widely used type, the percentage of use of Desktop GIS is quite higher in higher courses, specially in 9-10 and 11-13, thus agreeing the greater difficulty of using a Desktop GIS to the greater the age of students. We can link both findings, not only Web GIS is easiest to use than the others, also as the students increase their skills they can start adopting new and more difficult programs.

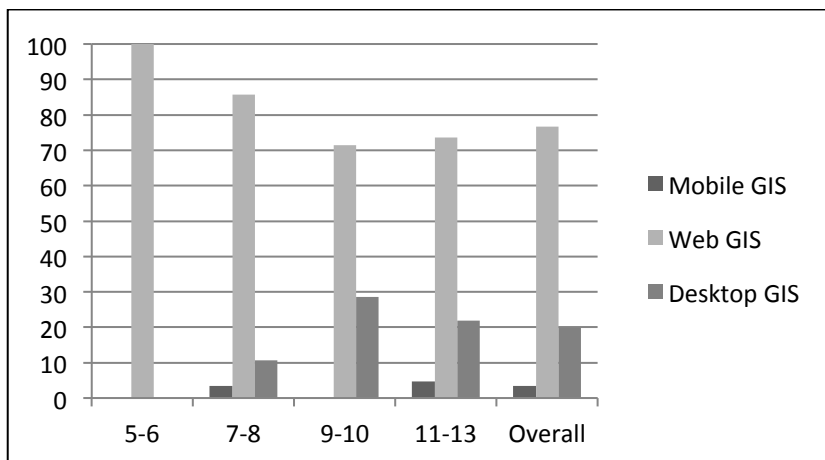


FIGURE N° 3. Percentage of typology of GIS programs used by course.

Within the preferred GIS types the frequency of use is in many cases casual. Teachers usually show one example of GIS program in one lesson per year. Only few programs with a frequency between 2 and 5 uses per year are used, possibly the more user-friendly programs and the more adapted to the syllabus exigencies. 46.9% of GIS using teachers have used Diercke WebGIS at least once, and 40.8% have used Schule WebGIS at least once, being their frequencies of use between 2 and 5 annual uses very common. This means both programs were very close to what a teacher wanted of an educational GIS to be.

3.2. Geographic Information Systems solve teaching problems

When we cross the Geography topics most treated with a GIS with the Geography topics perceived as most difficult by the sample, we found some coincidences that drive us to think that GIS help teachers to solve teaching problems. There are three main themes of Geography in which teachers use a GIS in the classroom: *Regional and local development* (26.83%), *Economic Geography* (14.63%) and *Climatology* (12.20%). To a lesser extent, *Population Geography* (9.76%), and the *Specific study of regions* (8.94%;

China specially) are also important. Although the climate stands out as a widely used subject, most of the topics dealt with are from Human Geography such as economic inequalities between regions or inequality in the distribution of the population, drawing the students' attention to socially relevant issues.

The most used scale within these topics is the global with 39.02% of the mentions. The intermediate scales –international, national and regional– have similar percentages between them, and is the local scale which registers a very low value (8.94%). The data tell us that GIS topics are shown to students with scales on which they have difficulty accessing or understanding through their direct experience. On the other hand the most used GIS are the Web GIS (79.67%) followed by large by the Desktop GIS (17.89%).

Regarding the perceived most difficult themes in Geography almost a third of teachers (28.92%) declare that *Climatology* is one of the most difficult subjects to teach in Geography. In the second position we found *Economic Geography* (22.89%), nevertheless the *Geography of the Soils* (12.85%) and the *Geomorphology* (6.83%) burst with great force in the categories on difficult subjects while they are marginal or nonexistent when dealing with GIS in the classrooms. Development, inequalities and demography are GIS issues used above their perceived difficulty, while soil and atmospheric processes are less utilized with a GIS, despite being perceived as rather difficult.

We see the relatively high concentration in a few frequencies and the presence of subjects that require some abstraction and understanding of complex phenomena. In contrast to the previous part, the topics of Physical Geography are linked to phenomena that take a long time to develop, the geological ones, or that affect different scales at the same time, the climatic ones. In general it seems that the main difficulty of teachers is to make understand the global Earth systems far removed from the daily experience of students and that intertwine very abstract concepts. The scale of application that gives more problems among teachers of the sample seems to be the global scale (50.2%). We can point out that, as we said, the greater abstraction and remoteness of direct experience increases the difficulty for teachers to deal with a topic of Geography.

In a brief the GIS are applied to the topics of Geography that teachers consider difficult to drive in classrooms as *Climatology* or *Economic Geography*, and inside them they give great importance to the study of inequalities, development, natural resources and demography. About 57% of the topics treated with a GIS were made on a global or international scale reflecting the usefulness of GIS to deal with current worldwide problems inside education (Nieto, 2017).

Previous studies like Thomas R. Baker, Palmer, and Kerski (2009) said that the most common subjects taught with GIS (90%) were: *Population* (20%), *Environmental*

themes (38%): *Climate change and weather, Water resources, Ecology, and Agriculture; Mapping, Topography as well as Borders* (27%). Economic topics, as trade, were used by 5% of respondents. In our study we found *Population* (9.76%), *Climatology* (12.20%), *Natural resources* (3.25%), *Agriculture* (2.44%), *Ecosystems* (1.63%), *Environmental protection* (1.63%) and *Cartography and GIS* (2.44%) altogether summarize 33.35%, while *Economic Geography* 14.63% for a total of 47.98%. Although there are significant differences of percentage between them the most common topics of *Climatology, Economics* and *Population* are shared between both studies as we can see on Figure 4.

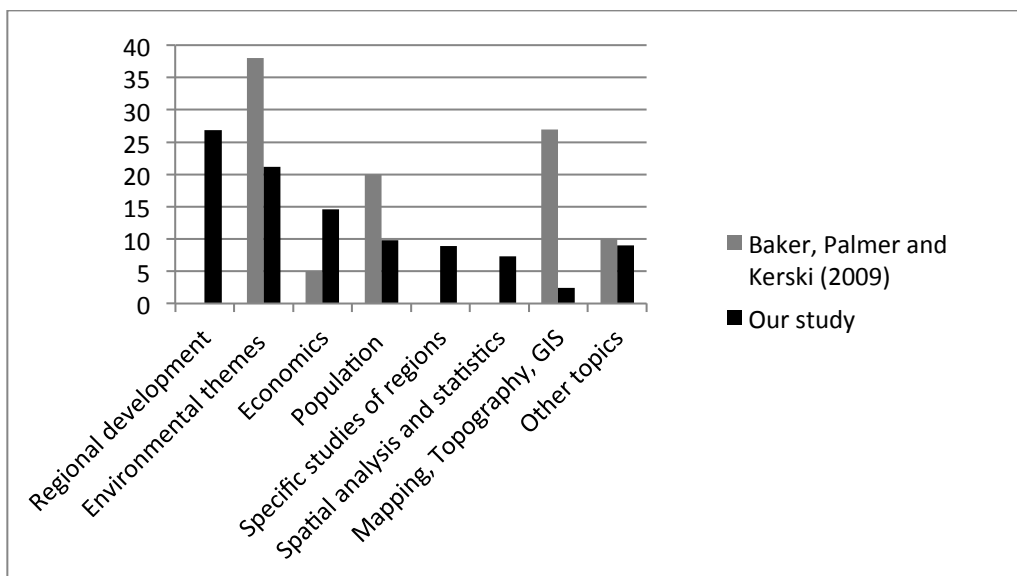


FIGURE N° 4. Comparison between studies about topics used with GIS in the classroom.

3.3. Predictive models for educative GIS use and its frequency

We selected two key variables *Teaching with GIS* (a dichotomous categorical variable) and *Frequency of use of GIS* (a reason variable) to predict the conduct of the sample respect to the educative practice with GIS. Our intention was to offer mathematical models from the observation of patterns that would explain and predict the behavior of those variables; therefore, we generated a logistic model for the teaching with GIS variable and a multiple linear model for the frequency of use variable.

For *Teaching with GIS* we used a set of 23 independent variables for 141 cases included in the analysis and the coding used for this dependent variable was 0=No and 1=Yes. From the total of independent variables we isolated two very significant variables using

a step model; and, eliminating the least influential from the rest, we arrived at an optimal three-variable model, with the highest R^2 explained and a high percentage of prediction.

The final variables used were *GIS teaching in grades 5-6* ($F=13.88$, $p=0.000$, X_a , range 0-1), *GIS didactic training on its own account* ($F=25.01$, $p=0.000$, X_b , Range 1-5) and *GIS technical training as teachers* ($F=7.58$, $p=0.006$, X_c , range 1-5). The model was correctly validated with an omnibus coefficient test and the Hosmer-Lemeshow test. The model summary measures using Cox and Snell R^2 and Nagelkerke R^2 are 25% and 34.8%, respectively. The resulting equation is: $Logit(p) = -2.453 - 1.527 X_a + 0.721 X_b + 0.43 X_c$ and the predictability of the model, based on the data we have compared with the values predicted for the subjects of the sample by the model, gives us an overall percentage of 79.4% of success in its prediction. This equation allows us to certify with a 79% of success that the variables that affect the use, or not, of GIS among teachers are the ones mentioned above. In other words: if we circumscribe GIS only at courses 7 upwards, we can reach that teachers train themselves in GIS didactics at least a week and they assist to a technical GIS training of half a day, they will have GIS use in the classroom.

The *Frequency of use of GIS* by teachers was treated from a set of 28 independent variables for 41 cases. The dependent variable ranged from values 1 and 39.5, the values of 0 (no GIS use in classrooms) were not taken into account for this model as were observed in the previous one. From these independent variables a step-by-step process was performed and resulted in the final three variables of our model. The variables selected were *Private use of Desktop SIG* ($F=38.957$, $p=0.000$, X_a), *GIS didactic training in the university* ($F=10,054$, $p=0.000$, X_b), and *GIS technical training on its own account* ($F=4.829$, $p=0.034$, X_c), all with a range of 1-5. The model complies with the Durbin-Watson test for residue independence (1.893) and the linearity assumption, but we cannot assert the residue normality or its homoscedasticity. The percentage of variability explained by the model is 62% ($R = 0.806$, $R^2 = 0.650$, adjusted $R^2 = 0.622$) with a standard error of 5.32 and the resulting equation is: $Y_i = -11.747X_a + 4.004X_b + 1.947 X_c$. Our model explains 62% of the results regarding frequency of GIS use in the classroom, the rest of the percentage (38%) would be explained by variables we don't know.

Respecting the prediction of the model we found that 63% of the mean of the previously observed data (MMRE) is away, being a reference value of 25% as the appropriate one. Due to the non-fulfillment of some assumptions and the margin of error in the forecast we can point out that there is some unknown variable that explains these differences; taking into consideration that the sample is very small this results in a less reliable model than the previous one. However, a large part of the variance (62%) is explained by the model and therefore allows us to clarify which are the main variables, still more when compared with other studies that reach only 19% using the same theoretical framework

(Lay et al., 2013). This means that our study aims better to the real causes that provoke the use of GIS among teachers than previous studies. If we can increase the GIS didactic training to half a semester in the university we could reach a frequency of use in the classroom of, at least, 5 times a year.

4. CONCLUSIONS AND IMPLICATIONS

The global assessment of our study indicates that in order to expand and optimize the didactic practice with GIS in the secondary education of Geography it is necessary to simplify its use. The results obtained show that educational GIS is neither simple nor in common use at *Gymnasium* in Baden-Württemberg. The GIS didactic practice, also, is ascribed to the theoretical models used, emphasizing the facility above the utility at the time of conducting the survey. Therefore we would be at a stage of the diffusion process that demands to direct the innovation towards the general public and not towards the experts.

The models seem to point that GIS isn't a suitable tool for initial courses 5-6 and that self-taught training is the basis for teaching with GIS (technical being the most important). The ease with the advanced programs (Desktop GIS) is capital because only those that have this expertise use GIS regularly. In combination with other variables the technical training received as teachers and the didactic training received at the university have much more relevance than individually.

The Web GIS is therefore usually used, since it is the most accessible and simple of the existing types of GIS, and in advanced courses with students with greater cognitive development. The most used Web GIS are those with editorial or academic backing: Diercke GIS, Klett GIS and WebGIS Schule.

There is also a confluence between the topics considered difficult and the topics most used with GIS, which makes these tools an aid to teaching. The treatment of these subjects is done on a global scale, far from the direct experience of the students. The themes most treated by the sample of teachers are in turn those subjects that the educational curriculum of Baden-Württemberg links with the use of the competence of geographical methodologies, which specifically mentions the GIS (Ministerium für Kultus, Jugend und Sport Baden-Württemberg, 2016).

We conclude, that in order to develop the educative practice with GIS in the future it is necessary to cultivate a clear and specific formation in the stage of teacher training and during its teaching work, to implement GIS in the secondary education Geography curriculum in the most appropriate courses with specific subjects and scales where the GIS proves to be more competent, and to use a Web GIS software adapted to those activities which has a backing of didactic materials from publishers.

4.1. Implications for the future

Starting from this paper and continuing the previous research we think there are some lines to develop in the future regarding educational GIS; we list here the most relevant we have found.

First of all it is necessary to carry out systematic empirical studies to demonstrate if the use of GIS in the secondary education of Geography really improves the results of the students compared to a traditional methodology. Previous studies (Viehrig, 2014; Schubbe, 2014) seem to prove that both teachers and students have not the enough training to take full advantage from the GIS methodology, and thus this field cannot be explored until they have those skills.

Also is important to enhance the mathematical predictive models presented here introducing new measurable and modifiable variables that could solve the “invisible variable problem”, starting, for example, with how the visibility and social influence affects the implementation of educational GIS from the theoretical models of other innovations or products.

Continuing to monitor the frequency and percentage of use of educational GIS in Geography in Baden-Württemberg in a few years comparing the evolution produced with the expectations of the theoretical model is necessary and, continuing with this line of thinking, to replicate the study in other regions of Germany, as well as along Europe and other selected counties of the world, well defined geographically from standardized criteria. In our case we have used the first level of analysis of the European Union, corresponding to regions above 3 000 000 inhabitants, to be able to establish a framework of analysis common to other studies.

And finally, to develop the confluence between difficult topics of Geography and topics used with a GIS to be able to establish which are the subjects that really need to be treated with GIS in the classroom with respect to the more traditional treatment or other didactic approaches.

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