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Effects of Thinking Style and Spatial Ability on Anchoring Behavior in Geographic Information Systems

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ABSTRACT

The authors propose an instructional use for Google Earth (a GIS application) as an anchoring tool for knowledge integration. Google Earth can be used to support student explorations of world geography based on Wikipedia articles on earth science and history topics. We asked 66 Taiwanese high-school freshmen to make place marks with explanatory notes and summaries (known as anchors) to serve as geographic references; they used anchors that were predefined by their teacher for subsequent geographic searches. Our investigation focused on the processes used to create anchors, how the students used anchors to perform search tasks, and the roles of thinking style and spatial ability on learning processes and performance. The 671 generated anchors were categorized as direct, indirect, symbolic, temporal, spatial, and challenging. According to our results, students with legislative thinking style tendencies created the largest number of anchors but rarely used them for subsequent search tasks; executive-style students tended to make symbolic and temporal spatial geographic references and regularly used the teacher-created anchors and the anchors created by judicial-style students were evenly distributed across all categories. In addition, low-spatial ability students tended to create direct geographic references and to use predefined anchors for all problem types.

Keywords

Anchoring behavior, Thinking style, Spatial ability, Geographic information system, Google Earth

Introduction

Information technology (IT) is at the center of educational reform and innovation (Dexter, Anderson, & Becker, 1999; Dias, 1999; Mehlinger, 1996; Moursund, 1992), with many countries establishing national guidelines for the incorporation of IT tools into their education systems (Kozma, 2003). Various open source and freeware information products based on the Web 2.0 co-creating and sharing model provide teachers with a range of tools for curriculum design and instruction. Google Earth (http://earth.google.com), a free three-dimensional geographic information system (GIS) released in June of 2005, offers innovative approaches to studying geography and earth science topics using simulated images (Doering & Veletsianos, 2007; Lund & Macklin, 2007; Patterson, 2007; Rutherford, 2008; Sherman-Morris, Morris, & Thompson, 2009). An example of a Google Earth user interface is shown in Figure 1.

In addition to providing support for situated learning, Google Earth can also be used as a platform for knowledge integration among multiple domains. Users can create place marks, add text and graphics to those place marks, save them, designate them as favorites, and share them. These functions can serve as anchors for student-written notes containing geographic references while students explore domains consisting of geography-based information. Students can apply anchors and place marks to multiple cognitive functions in order to cultivate creative thinking. Here we will describe our proposal for a novel instructional approach that employs Google Earth for learning concepts in geography, earth science, and history.

We believe that multidisciplinary learning activities associated with Google Earth can help students construct and integrate knowledge from multiple domains, but further research is required to determine the positive uses of GISs in learning to make sure that students do not get lost in multidimensional simulated spaces and that knowledge integration across multiple domains does not hinder learning. To address these issues, we observed student anchoring activities such as referencing and citing, and examined the effects of different thinking styles and spatial abilities on anchoring activities.

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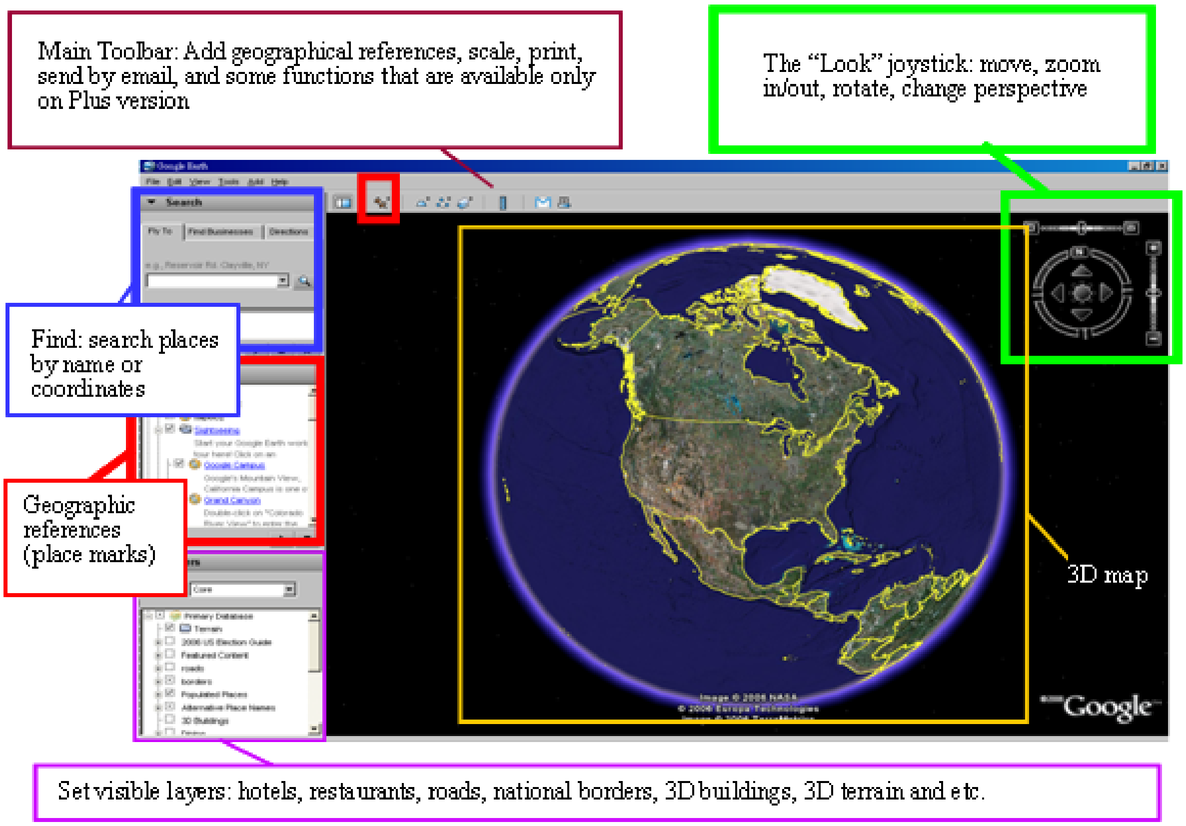


Figure 1. Screenshot of Google Earth user interface

GIS anchoring

Kienreich, Granitzer, and Lux (2006) combined a web-based map with a Brockhaus electronic encyclopedia to help readers access geographic references associated with place names, geological principles, historical events, and specific encyclopedic and geographic domains, and named their process geospatial anchoring. We used their work as the basis for our experiment, in which we introduced two exploration activities to a group of Taiwanese high school freshmen: creating anchors and using them to perform search tasks. Google Earth was used to establish a virtual learning context and to support student navigation for exploring world geography while they read web-based articles on earth science and history topics. Students were shown how to create geographic reference placemarks and how to write summaries of article content in placemark description fields. We use the term "anchor" to indicate a placemark that includes a geographic reference and explanatory notes, and "anchoring" to describe the act of creating and adding ideas to Google Earth placemarks. An example of a Google Earth anchor is shown in Figure 2. In the following activity, some anchors were predefined by the teacher for subsequent search applications. Students were given the option of using anchors to perform geographic searches or to otherwise use their geographic knowledge to find target images by rotating the Google Earth globe. We used our observations of these activities to investigate how anchoring behaviors can support knowledge integration.

The five types of geographic references defined by Kienreich, Granitzer, & Lux (2006) are direct, indirect, symbolic, temporal spatial, and challenging. Direct geographic references link a location with a place specifically mentioned in a text. One example of an indirect geographic reference is the association between the Forbidden City Museum and Beijing. Symbolic references connect geographic objects with a set of objects mentioned in an article—for example, a Greenland anchor may be linked to an article on glaciers. Temporal spatial references are tied to historical events such as wars and scientific discoveries. Challenging references involve links requiring additional information. In the present study, direct and indirect references required the application of geographic knowledge, symbolic references focused on earth science knowledge (e.g., geology, climate), temporal spatial references required knowledge of historical events, and responses to challenging geographic references required multiple sources of knowledge across several domains.

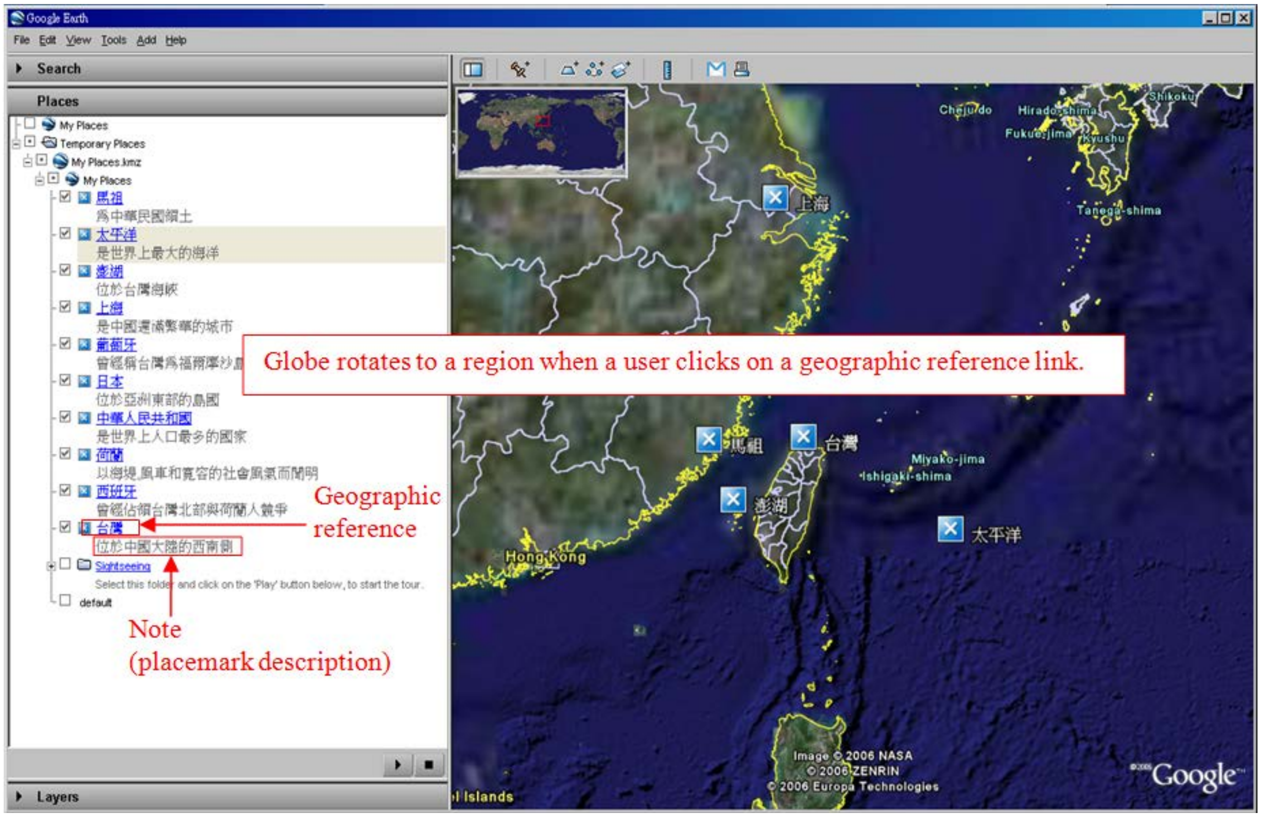


Figure 2. Google Earth anchor example

Spatial ability and learning functions

According to Greenfield (1984), navigation performance in a virtual space is largely dependent on spatial ability. This competency is generally believed to have two components: orientation and visualization (McGee, 1979). Lohman (1979) defines spatial ability as the ability to generate, retain, retrieve, and transform well-structured visual images, while Pellegrino and Hunt (1991) define it as the ability to reason about movement in a visual field. Gorgorió (1998) has proposed the concept of spatial processing ability, which she defines as the ability to fulfill the mix of mental operations required to solve spatial tasks. This includes skills tied to imagining and visually decoding spatial objects, relationships, and transformations, plus the ability to encode them verbally. Schofield and Kirby (1994) define spatial ability as the ability to visualize spatial relationships, including transforming objects from 3D to 2D, and identifying shapes in two-dimensional spaces. Google Earth users view a three-dimensional globe from the perspective of an orbiting astronaut. The ability to move, identify, locate, compare, rotate, and transform objects in 3D entails spatial relations, visualization, and orientation processes. Our assumption is that learners' behaviors in 3D GISs are tied to their ability to create and work with mental images—a type of spatial ability.

Thinking style is an important aspect of the learning process (Zhang & Sternberg, 2005). The list of researchers who have illustrated the significant contributions of thinking style to academic achievement in traditional environments includes Bernardo, Zhang, and Callueng (2002), Cano-Garcia and Hughes (2000), Grigorenko and Sternberg (1997), Zhang (2008), and Zhang and Sternberg (2005). Fan, Zhang, and Watkins (2010) have done the same for hypermedia learning environments. Thinking style represents personal tendencies and attitudes toward using one's abilities (Sternberg, 1994, 1997). According to Sternberg, it is closely associated with mental processes and preferences, with all individuals having a preferred thinking style for dealing with life problems. He lists the five dimensions of mental self-government as function, form, level, scope, and leaning, and the three function categories as legislative (preferring one's own way of doing things), executive (concerned with accomplishing assigned tasks within a set of guidelines), and judicial (tending to evaluate rules and processes, and preferring problems that require analysis). During learning activities, students generally set goals according to their individual habits and thinking styles. Therefore, we predicted that thinking style would influence our participants' anchoring activities.

Study purpose

For this investigation we defined the five above-described anchor types and considered the effects of learner thinking style and spatial ability on anchoring behaviors and learning performance. In addition to the anchoring activity, we designed a search activity to determine whether students used anchors as support tools or shortcuts for task completion, and whether learning outcomes from the first activity affected subsequent search tasks. Our goal was to determine if and how anchoring behaviors during learning activities are affected by individual differences in spatial ability and thinking style. In this study, we used three thinking styles (legislative, executive, and judicial) and three levels of spatial ability (high, medium, and low) as independent variables and two types of anchoring behaviors (creating and using anchors) as dependent variables. We established five research questions:

- Is anchor creation in a GIS activity affected by thinking style?
- Is anchor creation in a GIS activity affected by level of spatial ability?
- Is the use of anchors in a GIS activity affected by thinking style?
- Is the use of anchors in a GIS activity affected by level of spatial ability?
- Is search performance in a GIS activity affected by thinking style, spatial ability, or anchoring behaviors?

Method

Participants and measures

The final sample of 66 Taiwanese high-school freshmen was established from an original sample of 237 students. Selections were made based on results from Sun and Wang's (2004) Thinking Styles Questionnaire for Junior High School Students, a modification of Sternberg's (1997) Thinking Styles Inventory. The 24 items were designed to identify legislative, executive, and judicial thinking styles (eight each). An example of legislative style is "I like to deal with academic problems that I can use my own methods to solve"; an example of executive style is "I prefer work tasks or problem-solving according to clear rules and operating guidelines"; an example of judicial style is "I like to analyze, evaluate, and compare different views." All responses were given along a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Internal consistency coefficients (α) for the questionnaire and its three dimensions have been measured as 0.83 overall, 0.75 legislative, 0.73 executive, and 0.74 judicial (Sun & Wang, 2004). All students in the final sample had high scores in one style and low to medium scores in the other two.

To examine the effects of different spatial processing abilities on anchoring behavior, we ranked the 66 students according to their scores on a spatial ability test developed by Lu, Lu, and Ou (1994) (0.76 internal consistency coefficient). The final groups consisted of 20 low, 26 mid, and 20 high-spatial ability students. In the spatial ability tests, students were asked to choose one of four graphs that most resembled the original; the direction of the original graph was different from the directions of the other four.

The final sample consisted of 40 male students and 26 female students. The majority of participants stated that they had approximately seven years of experience using computers, mostly for Internet surfing, email, and instant chat communication. None had any experience with a learning activity based on Google Earth.

Procedure

The experiment was conducted over a four-week period. During Week 1, thinking style and spatial ability tests were administered during a single 45-minute class period. To increase system familiarity and to reduce the impact of insufficient computer experience, during Week 2 we gave participants 45 minutes of anchoring training and Google Earth instruction. The first activity was assigned during a 45-minute period in Week 3. Students were asked to view maps and create anchors according to article content. English translations and geographic details for major locations were given in the assigned articles to reduce interference due to language ability or background knowledge. The second activity was done during a 45-minute period in Week 4; during this session, students were asked to complete fifteen search tasks. Here we will describe the two activities in detail:

- *Locate geographic references based on Wikipedia article excerpts*. An example of geographic content is "Taiwan is located in eastern Asia, western Pacific"; an earth science example is "Taiwan is an island extruded and uplifted by the Eurasian and Philippine Sea plates"; a history example is "From 1626 to 1642, northern Taiwan was occupied by Spain." We purposefully provided articles about familiar locations and basic geographic and historical knowledge in an effort to reduce the effects of individual differences in prior knowledge. Students were instructed to read the articles, use the content to create placemarks (map locations), and add brief explanations to each placemark. They were permitted to rotate the Google Earth globe to perform searches, and to use English names or coordinates to access locations of interest. The purpose of this task was to determine how the students connected textual content to geographic location and how they created geographic references on a map. Anchor numbers and types were evaluated to determine which kinds of subject knowledge were easily discovered and recorded. Anchors were classified according to content; an example of a symbolic geographic reference/anchor would be a placemark on Jade Mountain with the descriptor "highest mountain in Taiwan." Off-topic anchors or anchors with incorrect explanations were considered invalid and excluded. Students were informed that their second search activity would be based on the same article as in the first; therefore, they could customize their anchors with their own notes.

- *Perform multiple photograph search tasks*. During their searches, students could choose between using one of 30 predefined geographic references/anchors or referring to details provided in the search problem texts. Solutions based on other software functions or methods were disallowed. To determine which anchor types were used most often, we selected five predefined anchors that corresponded to the five problem types: direct, indirect, symbolic, temporal-spatial, and challenging (three of each type, for a total of 15 problems). In all, 30 predefined anchors were established by an instructor prior to the experiment. While predefined anchors may have been historically or geographically associated with correct answers, they did not necessarily contain correct answers. Anchors mostly served as shortcuts for students to quickly move to target areas. Students were also asked to upload map screenshots that matched targets in terms of direction, distance, and angle.

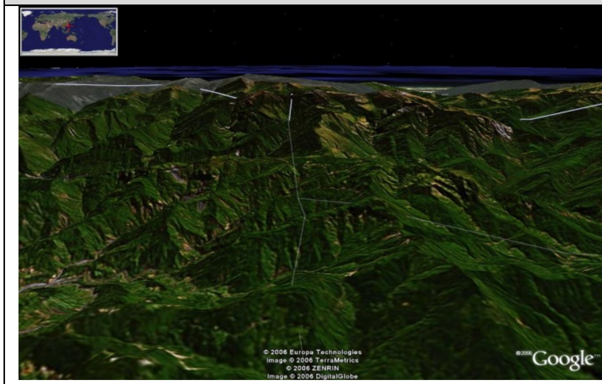
Scoring

As part of activity 1, students uploaded the anchors they created as (keyhole markup language zipped) kmz files. Figure 2 presents a list of all anchors created by one student, categorized as direct, indirect, symbolic, temporal spatial, or challenging based on Kienreich et al.'s (2006) geographic reference definitions; the same results are presented in English as Table 1. Activity 2 scores reflect differences between target photos and search results. The highest possible score of 5 indicated that a student's search results completely matched the target in terms of direction, distance, and angle. Scores for all problems were summed; a scoring example is shown in Figure 3.

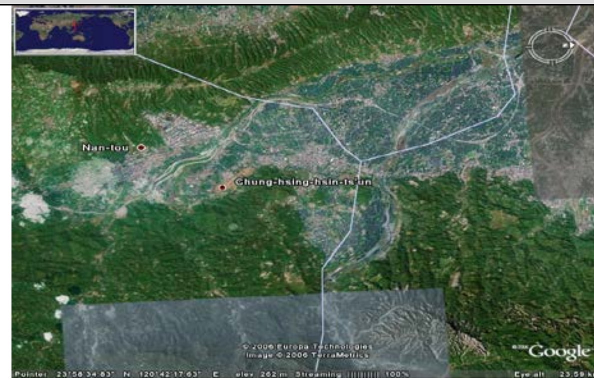
Table 1. Anchor list for student S001

No.	Anchor Name	Anchor Note	Anchor Type
1	Matsu	Republic of China territory	Direct
2	Pacific Ocean	World's largest ocean	Symbolic
3	Penghu	In the Taiwan Strait	Direct
4	Shanghai	A bustling city in China	Indirect
5	Portugal	Home of Portuguese, who called Taiwan "Formosa"	Temporal spatial
6	Japan	An island country in East Asia	Symbolic
7	People's Republic of China	Most populous country in the world	Challenging
8	Netherlands	Known for dikes, windmills, and a tolerant society	Challenging
9	Spain	Once occupied northern Taiwan and competed with the Dutch	Temporal spatial
10	Taiwan	Located southwest of China	Indirect

Search task: Jade Mountain



(a) Target image.



(b) Search result for S001.

Student S001 was awarded two points because the search result was close to the target, but did not match in terms of direction, distance, or angle.

Figure 3. Image search scoring example

Results

Effects of thinking style on creating anchors

During the first activity, participants created 111 direct, 86 indirect, 161 symbolic, 174 temporal spatial, and 85 challenging anchors; anchor numbers according to thinking style are presented in Table 2. Chi-square test results indicate a significant relationship between anchoring behavior and thinking style ($\chi^2(8) = 44.520$, $p < .001$). According to the data on relationships between thinking style and anchoring behavior, legislative-style students created the largest number of anchors and showed preferences for temporal spatial, direct, and symbolic anchors, likely reflecting their enthusiasm for discovering new knowledge (Fig. 4a). Executive-style students created greater numbers of symbolic and temporal spatial anchors. Statistical significance was not found for the main effect of judicial thinking style. Among judicial-style students, anchors were evenly distributed across all categories.

Table 2. Anchor type according to thinking style (*n* = 66)

Thinking style	Anchor Type					Overall	χ^2(column) d = 4
	Direct	Indirect	Symbolic	Temporal spatial	Challenging		
Legislative (n = 22)	61	39	55	68	37	260	14.231**
Executive (n = 22)	18	16	70	63	14	181	85.436***
Judicial (n = 22)	32	31	36	43	34	176	2.580
Overall	111	86	161	174	85	617	56.736***
χ^2(row) d = 2	26.000***	9.512**	10.820**	6.034*	11.035**	21.592***	

**p* < .05, ***p* < .01, ****p* < .001

Effect of spatial ability on anchoring

Results for numbers of anchors created by the participants according to spatial ability are presented in Table 3. A significant relationship was found between spatial ability and anchoring behavior ($\chi^2(8) = 65.175$, $p < .001$), and a strong main effect of spatial ability on anchoring was also observed ($\chi^2(2) = 17.906$, $p < .001$). Overall, students in the mid-spatial ability group created larger numbers of anchors compared to the high- and low-spatial ability students

(Fig. 4b). Our results also indicate that students in the low-spatial ability group preferred direct anchors, mid-spatial ability students favored symbolic and temporal spatial anchors, and high-spatial ability students preferred symbolic anchors. No significant differences were noted among these groups in terms of indirect anchor numbers.

Table 3. Anchor type according to spatial ability (n = 66)

Spatial ability	Anchor Type					Overall	χ^2(column) d = 4
	Direct	Indirect	Symbolic	Temporal spatial	Challenging		
Low (n = 20)	63	24	28	42	20	177	34.667***
Mid (n = 26)	35	30	68	83	39	255	42.235***
High (n = 20)	13	32	65	49	26	185	44.595***
Overall	111	86	161	174	85	617	56.736***
χ^2(row) d = 2	33.946***	1.209	18.497***	16.586***	6.659*	17.906***	

*$p < .05$, ***$p < .001$

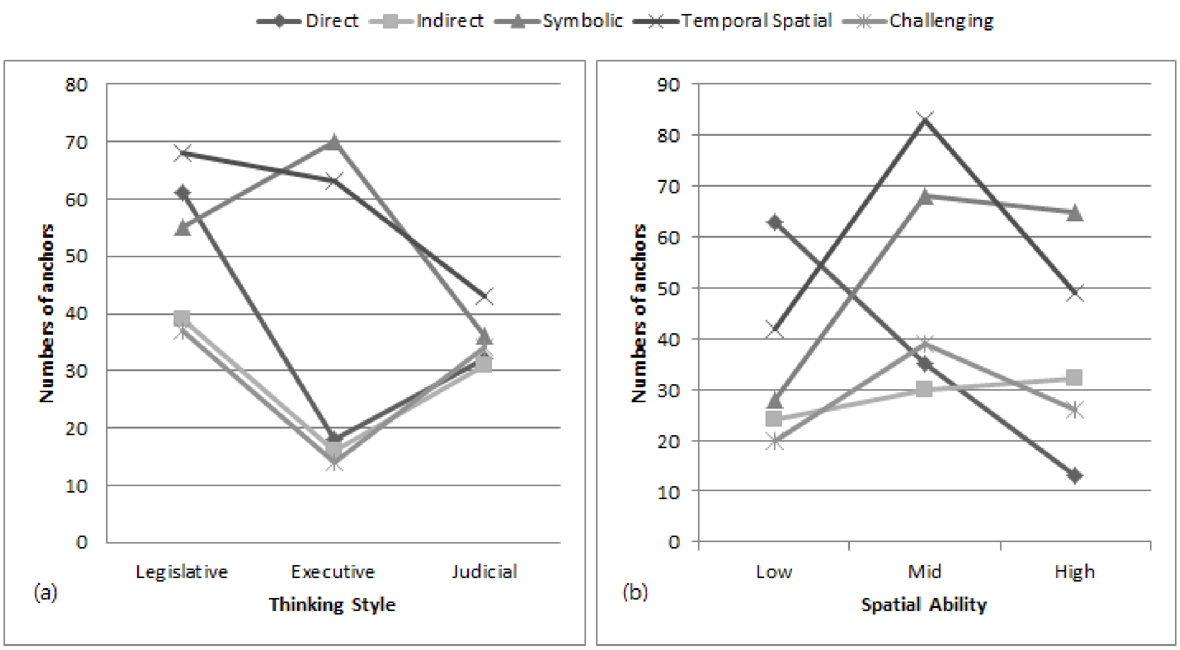


Figure 4. (a) Relationships among thinking styles and numbers of created anchors; (b) Relationships among spatial ability levels and numbers of created anchors

Effects of thinking style on anchor usage

During the search activity, the 66 participants used predefined anchors 78 times for direct geographic reference problems, 95 times for indirect problems, 130 times for symbolic problems, 101 times for temporal spatial problems, and 143 times for challenging problems. We performed a one-way ANOVA to analyze the average number of problems (out of 15) that were solved with the help of predefined anchors. Our results show that executive-style students (M = 11.05) used more anchors than judicial (M = 7.45) or legislative-style students (M = 6.36). In other words, executive-style students (who tend to conform to rules and prescribed processes) showed the strongest preference for predefined anchors. Results from Chi-square tests examining the use of predefined anchors are shown in Table 4. No statistically significant relationships were found between anchor usage and any of the three thinking styles ($\chi^2(8) = 4.145$, $p = .844$), but significance was noted for the main effects of thinking style ($\chi^2(2) = 31.857$, $p < .001$) and problem type ($\chi^2(4) = 25.751$, $p < .001$). These data also indicate that executive-style students showed a preference for predefined anchors, but they also indicate that all students showed the same preference when addressing challenging and symbolic problems. Specifically, the results indicate that executive-style students tended to use predefined anchors for all problem types, legislative-style students were more likely to use them to solve symbolic and challenging problems, and judicial-style students were more likely to use them to solve challenging geographic reference problems.

Table 4. Predefined anchor usage according to thinking style (*n* = 66)

Thinking style	Problem Type					Overall	χ^2(column) d = 4
	Direct	Indirect	Symbolic	Temporal spatial	Challenging		
Legislative (n = 22)	18	23	38	23	38	140	12.500*
Executive (n = 22)	39	43	53	50	58	243	4.798
Judicial (n = 22)	21	29	39	28	47	164	12.707*
Overall	78	95	130	101	143	547	25.751***
χ^2(row) d = 2	9.923**	6.653*	3.246	12.257**	4.210	31.857***	

*$p < .05$, **$p < .01$, ***$p < .001$

Effects of spatial ability on anchor usage

No statistically significant relationships were noted between spatial ability and the use of anchors for any problem type ($\chi^2(8) = 1.656$, $p = .990$). However, the results shown in Table 5 indicate statistical significance for the main effect of spatial ability ($\chi^2(2) = 23.74$, $p < .001$), suggesting that low-spatial ability students had a stronger preference for predefined anchors compared to students in the other two groups. No significance was noted for the simple main effect of low-spatial ability, meaning that students in this category did not show a preference for any problem type and tended to use predefined anchors for all problem types. Statistical significance was also noted for the simple main effects of mid and high-spatial ability ($\chi^2(4) = 10.131$, $p < .05$, $\chi^2(4) = 11.000$, $p <$m.05). Students in these two groups preferred using predefined anchors to solve challenging and symbolic geographic reference problems. For direct and symbolic geographic reference problems, mid- and low-spatial ability students showed strong preferences for predefined anchors. None of the groups expressed significant preferences for using anchors to solve indirect, temporal spatial, or challenging geographic reference problems. Students in the high-spatial ability group tended to use anchors to solve challenging and symbolic geographic reference problems.

Table 5. Predefined anchor usage according to spatial ability (*n* = 66)

Spatial Ability	Problem Type					Overall	χ^2(column) d = 4
	Direct	Indirect	Symbolic	Temporal Spatial	Challenging		
Low (n = 20)	34	39	52	41	53	219	6.365
Mid (n = 26)	28	35	48	35	52	198	10.131*
High (n = 20)	16	21	30	25	38	130	11.000*
Overall	78	95	130	101	143	547	25.751***
χ^2(row) d = 2	6.462*	5.642	6.338*	3.881	2.951	23.740***	

*$p < .05$, ***$p < .001$

Effects of thinking style, spatial ability, anchoring behavior, and use of anchors on search performance

The average search task score for all of the participating students was 57.85 (maximum 75) (SD = 8.663; skewness = −.573). Results from a one-way independent sample ANOVA indicate that executive (M = 61.68) and judicial style (M = 59.32) students performed significantly better than legislative-style students (M = 52.55) (F = 8.015, $p < .01$). According to these data, students who tended to strictly follow rules or to carefully choose the proper time to use an anchor performed better overall, but no statistically significant differences were found among students at different spatial ability levels.

We conducted Pearson correlation analyses to examine whether student search performance in the second activity was affected by anchoring behavior in the first activity or the use of predefined anchors in the second activity. As shown in Table 6, search performance was not significantly associated with the number of anchors created in activity 1, with the exception of students who preferred creating direct anchors. However, positive relationships were found between student performance on search tasks and the frequency of using predefined indirect, temporal spatial, and challenging anchors, suggesting that proper guidance and navigation enhanced learning effectiveness.

Table 6. Results from Pearson correlations involving anchors, anchor usage, and search performance (n = 66)

		Anchor Type					Search Task Score
		Direct	Indirect	Symbolic	Temporal Spatial	Challenging	
Problem Type	Direct	.044	−.204	−.129	.060	−.167	.219
	Indirect	.141	−.341**	−.039	−.207	−.163	.300*
	Symbolic	.212	−.256*	−.190	−.102	−.179	.118
	Temporal spatial	−.023	−.206	−.121	.059	−.217	.327**
	Challenging	.040	−.107	−.194	−.226	−.324**	.271*
Number of predefined anchors used		.101	−.279*	−.169	−.104	−.265*	.312*
Search task score		−.399**	−.033	.204	.051	−.041	—

*$p < .05$, **$p < .01$

Discussion

Our goal was to create a method for encouraging students to search for geographic locations based on textual information, an approach that fits well with the constructivist emphasis on establishing learner knowledge through orientation, elicitation, restructuring, application, and review (Driver & Oldham, 1986). Instruction consisted of an anchoring activity and a search activity based on Google Earth, with students exploring places associated with concepts or events—for example, the location of the National Palace Museum and the Spanish occupation of northern Taiwan. The anchoring activity encouraged the extraction of essential concepts from Wikipedia articles, with students restructuring knowledge in ways that reflected their individual learning styles. Students reviewed their anchors and applied them to the search activity. We predicted that students would internalize knowledge during the anchoring and search processes.

We developed open-ended tasks and allowed students to select locations of interest on 3D maps for the purpose of creating geographic references. These references encouraged students to apply and integrate domain knowledge through the use of Google Earth maps. In addition, by placing anchors on 3D maps, students had the opportunity to develop a deeper understanding of article content, thereby completing search tasks more easily. According to Beane’s (1997) integrated curriculum concept, this type of situated learning activity benefits students in terms of conceptual understanding and integration. Our results indicate that the students constructed similar numbers of each type of anchor to complete their tasks. For their direct or indirect anchors they emphasized geographic knowledge, for their symbolic anchors they emphasized earth science knowledge, and for their temporal spatial anchors they emphasized history knowledge. This suggests that Google Earth can be used as a platform for knowledge integration, and that the anchoring approach is suitable for teaching geography, earth science, and history concepts.

Taking thinking style into account, our results indicate that executive-style students were the most likely to create symbolic and temporal spatial anchors. Their careful reading of the content of earth science and history articles is characteristic of an executive-learning style, as was their use of knowledge-based notes associated with article content. However, they often cut-and-pasted article content to use as anchor text—a strategy considered a surface approach (Dunkin & Biddle, 1974). Further, they were rarely willing to search for place locations or to create direct or indirect anchors.

Legislative-style students tended to create direct and temporal spatial anchors and to establish much larger numbers of anchors compared to students in the other groups—an indicator of their enthusiasm for exploring new knowledge. Judicial-style students did not show a preference for any single anchor type, perhaps an indicator of their analytical tendencies. Legislative-style and judicial-style students were willing to create challenging anchors that required additional information from knowledge sources across multiple domains. In other words, the legislative- and judicial-style study participants used deep approaches to learning, while executive students tended to use a surface approach—a finding that agrees with results reported by Zhang (2000) and Zhang and Sternberg (2000). Since the task we used in our experiment involved greater cognitive complexity and encouraged students to create their own knowledge, we believe it facilitated the use of a legislative approach to learning.

Our results also indicate a relationship between anchoring behavior and spatial ability. Students with low-spatial ability scores showed a preference for direct anchors—perhaps as a timesaving tactic, or an indication that they found it difficult to deal with spatial relationships. Both mid- and high-spatial ability students favored symbolic and spatial temporal anchors. The higher level of detail in the articles used for this study is a likely explanation for these preferences. Mid-spatial ability students also showed a tendency to create more anchors. A possible explanation for why low-spatial ability students created fewer anchors is their relative lack of skill in fixing positions on maps, and a possible explanation for why high-spatial ability students created fewer anchors is their perception that recording direct geographical references was unnecessary, since their spatial abilities were sufficient for meeting the requirements of the location search test.

Regarding anchor-citing behaviors, we found that executive-style students were more likely than others to use predefined anchors for search tasks, perhaps due to their characteristics of following rules and finding practical solutions to problems (Sternberg, 1997). Among more analytical (judicial-style) students, their use of anchors was consistent across all problem types. We also noted that legislative-style students were more creative and attentive when using Google Earth, and were therefore less likely to use predefined anchors. Low-spatial ability students clearly had difficulty rotating the Google Earth globe when searching for targets and therefore relied more on predefined anchors. As expected, high-spatial ability students enjoyed rotating the globe to perform their searches, suggesting that they were more likely to benefit from such a system for learning earth science and geography concepts. In short, the data suggest that the executive-style and low-spatial ability students required more structured learning aids and scaffolding when using the 3D GIS.

In terms of search performance, students who showed preferences for predefined anchors performed better on search tasks, suggesting that anchors significantly enhanced search performance to the degree that it was not affected by spatial ability. A possible explanation is the fixed nature of search task solutions versus potential variation in strategy. Accordingly, existing and available anchors may have facilitated searches in the same manner as shortcuts. A standard approach to answer assessment may be supportive of an executive style; our results indicate that executive-style students outperformed their legislative-style classmates. This finding is in agreement with reports from Cano-Garcia and Hughes (2000) and Zhang and Sternberg (1998) of positive correlations between executive thinking style and achievement. In Cano-Garcia and Hughes's study, students who explicitly stated their aversion to creating and planning (negative legislative) and those who favored existing rules and procedures (executive) achieved higher scores. In the present study, even though judicial-style participants used fewer predefined anchors, they earned higher scores on their search performance tasks. This unexpected finding, which suggests that judicial-style students were more analytical, careful, and precise in their use of available anchors, is an example of Zhang's (2004) observation of mixed ways in which judicial-style tendencies contribute to academic achievement.

According to Sternberg and Zhang (2005), "What is valued in one time and place may not be valued in another". According to our data, executive-style students were very capable of organizing article knowledge for use with Google Earth, but less capable of constructing original knowledge. Still, they were skillful at finding landscape photographs via various anchor types that served as task completion shortcuts. In contrast, legislative style students were more active in creating multidisciplinary knowledge anchors, suggesting that classroom instruction might benefit from teacher efforts to match executive- and legislative-style students for activities involving collaborative knowledge construction. In accordance with social constructivist principles that encourage learner discussion, negotiation, and coordination for integrating new information (Resnick, 1989), we believe that matching these types of students for lessons involving Google Earth-like activities may lead to enhanced knowledge construction.

Conclusions

GIS activities have been used in teaching curricula for subjects such as archaeology (Hespanha, Goodchild, & Janelle, 2009), sociology (Grady, 2007), economics (Booker, 2007), and criminology (Harries, 1999). For the present study, we used a free GIS application, Google Earth, to create a teaching scenario in which learners were asked to organize article content in terms of geographical references and to present their results on 3D maps. The goal of the activity was to help students establish connections between geographic locations and article content, thus building a deeper understanding of the meaning and value of specific knowledge. In such scenarios, instructors serve as navigators and facilitators, while students act as explorers and knowledge producers. Google Earth supports learning in a manner that matches Dias and Atkinson’s (2001) claim regarding characteristics for integrating technology into curricula, as well as Moersch’s (1999) fourth-level integration of technology into classrooms. We believe this activity can be used to help establish critical thinking and knowledge construction skills leading to higher-order learning. According to our study results, learner use of Google Earth’s anchoring feature is affected by a combination of thinking style and spatial ability. Further, we found little variation in terms of spatial ability, which can be enhanced through cumulative experience in the use of 3D GISs or maps. In summary, we found that thinking style exerted a stronger influence than spatial ability on learning among the study participants.

Teachers play key roles in the integration of IT tools into learning environments (Hsu & Sharma, 2008; Jung, 2005; Vanderlinde & van Braak, 2011). They are expected to facilitate learning and to make learning meaningful for individual students rather than to simply provide knowledge and skills (Roblyer, 2006). Students with different thinking styles tend to prefer specific teaching approaches (Zhang, 2004). For example, legislative- and judicial-style students prefer approaches that emphasize conceptual change, and executive-style students prefer approaches that emphasize information transmission. In their roles as facilitators and advisors, teachers can benefit from emphasizing learning processes rather than learning outcomes, and from designing materials and learning contexts that match the needs of a range of learning styles. They can support their students’ self-learning efforts by providing them with greater decision-making autonomy. Tools such as Google Earth can be used to observe student anchoring behaviors and to identify how they use anchors to construct knowledge networks; teachers can then use this information to incorporate anchoring activities into learning, thereby transforming unidirectional and static learning processes into those in which pluralistic, life-oriented, and interesting experiences are accumulated (Jonassen, 1996; Sprague & Dede, 1999).

Limitations

Anchoring in Google Earth requires strong IT skills and experience. Therefore, the instructional activities described in this paper may not be suitable for students who are not proficient in the use of computers. Another potential limitation concerns the article topics, since familiarity with content likely affected the anchoring behaviors of the study participants. The articles used in this study were on geography, earth science, and history topics, which may have influenced student decisions to create geographic, symbolic, and temporal spatial anchors. Students may express different anchoring preferences for other disciplines. Finally, we asked a teacher to establish 30 anchors in advance to support our observations of predefined anchor usage. The specific ways that students respond to anchors created by others requires further exploration.

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