Identifying Important Geographic Information System Concepts in Interdisciplinary Research: An analysis of Google Scholar

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1. Introduction

Academic research projects allow a unique opportunity to analyse and solve the problems of society. These problems, regardless of their perceived size, are complex and multi-faceted and, as such, "…resist understanding or resolution when approached from single disciplines." (Golding, 2009, pp. 2); to truly understand them, multiple disciplines would need to be incorporated. This is interdisciplinary research (IDR), which is defined as "… any study or group of studies undertaken by scholars from two or more distinct scientific disciplines." (Aboelela et al., 2007, pp. 341).

By its nature, IDR will makes use of many tools from different fields of study; more specifically, many IDR projects the authors work on utilise Geographic Information Systems (GISs), as they are a fundamental research tool for analysing spatial data. Those from various disciplines wishing to look into locational issues have embraced this technology, "…largely from the fact that GIS offered tremendous potential as an analytical system in a large research and information management environment." (Mara Chen, 1998, pp. 261) and as an integrator of disparate datasets. This tool has gone beyond one simply meant for geographers to something everyone can use. As stated by Schuurman (2009):

"Ironically, over the ensuing ten years, geographic information and analysis has slowly migrated somewhat out of the domain of geography into web-based open access forums. Large numbers of people are experimenting with naïve mapping, mash-ups of multiple forms of geographic information. And almost everyone uses web-based map queries to navigate around cities and between them." (Schuurman, 2009, pp. 573)

However, it can be said that GIS is hard to use (Traynor & Williams, 1995, pp. 288), and IDR itself is difficult (Locker, 1994, pp. 139). This paper examines the use of GIS in IDR projects, and, following a brief review of general challenges in IDR research and proposed solutions, considers the following questions:

- What challenges have people actually encountered in IDR projects that use GIS and how do they suggest solving them?
- How is GIS currently employed in IDR and which disciplines are actively utilising it?
- Which important GIS concepts set forth by GIS training curricula have been employed in practice by these disciplines when using GIS in IDR settings?

2. Background - IDR Challenges and Solutions

Though quite powerful, IDR is not without its perils and pitfalls. To permit a review of these in the context of GIS IDR projects, this section first reviews the challenges encountered in general IDR projects, along with suggested solutions. This is followed by a short review of GIS curricula, which will permit comparison between the GIS concepts proposed as relevant to GI specialists against those applied in practice in IDR settings.

2.1 – IDR Problems and Proposed Solutions

As a result of an extensive review of over 50 IDR articles, common problems become apparent and can be summarised as follows (listed from most to least commonly mentioned in the literature):

- Difficulties Related to Collaborating with Other Disciplines
- Personal Issues
- Time Constraints
- Intransigence from Current Institutional Structures
- Problems Being at the Interface Between Disciplines
- Lack of Opportunities for People
- Licencing and Ownership Ambiguities
- Lack of Local Level Management[1]

There can be many hurdles to IDR; however, with the right approach, problems can be avoided early on thereby increasing the probability of the project being successful. From the same literature review, potential solutions were suggested as well, which, again, from most to least commonly mentioned in the literature, are as follows:

- Provide Training on Technical and Supplemental Skills
- Build Relationships with Members of the Group
- Include Senior Staff and Interested Parties
- Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation
- Increase Funding Opportunities and Adapt Existing Ones for IDR
- Incentivise IDR with Support and Rewards
- Establish an Institutional Structure that Prioritises IDR
- Discourage Disciplinary "Selfishness"[2]

2.2 – GIS Curricula

It's because of the technology's ubiquity, improved usability, and applicability to analyses performed by a range of disciplines that there is interest in applying GIS to a variety of projects. However, to adeptly use GI software, one must still learn concepts core GIS specialists know in order to operate it (Traynor & Williams, 1995, p. 288). When learning

[1] Please refer to "Common Challenges and Suggested Solutions in Interdisciplinary Research" (Rickles, 2014) for a full list of references

[2] Please refer to "Common Challenges and Suggested Solutions in Interdisciplinary Research" (Rickles, 2014) for a full list of references

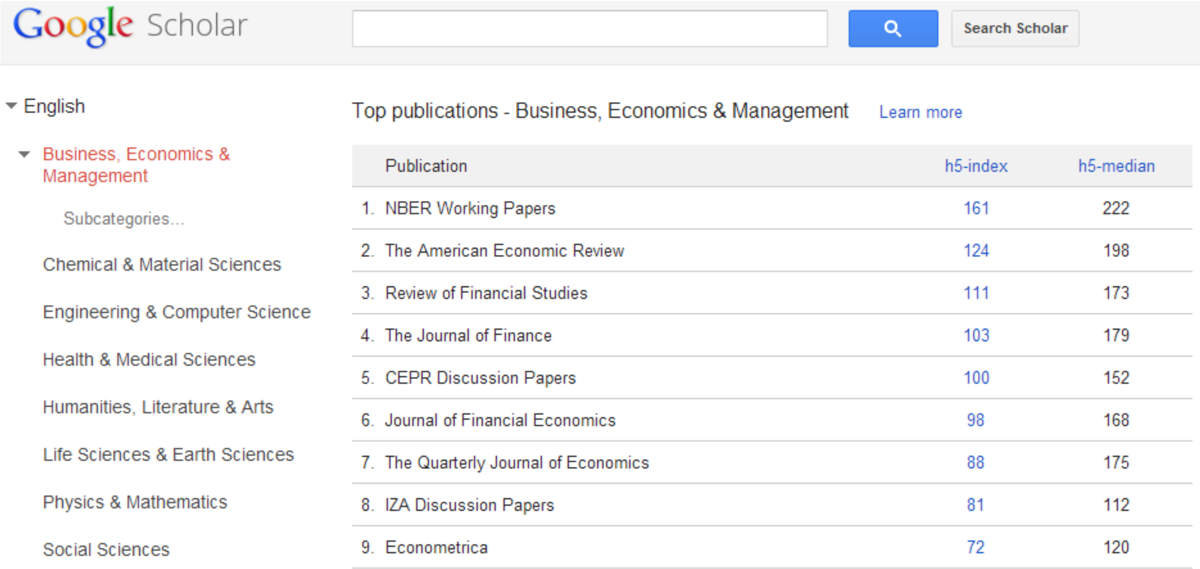
GIS, many scholars have tried to establish curricula to ensure coverage of important topics; one of which being the Geographic Information Science & Technology Body of Knowledge (GIS&T BoK), established in 2006 by David DiBiase and a team of editors. Developed by a large number of professionals, coordinated by the Education Committee of the University Consortium for Geographic Information Science (UCGIS) and published by the Association of American Geographers (AAG), the GIS&T BoK hopes to prepare students for success in the variety of professions that rely upon geospatial technologies. It also addresses shortcomings from earlier systems implemented internationally, namely, broadening topics to encompass the contemporary scope of the technology and current applications of the software that were not previously accounted for. In doing so, the GIS&T BoK identified 10 major Knowledge Areas of geospatial concepts: Analytical Methods, Conceptual Foundations, Cartography and Visualisation, Design Aspects, Data Modeling, Data Manipulation, Geocomputation, Geospatial Data, GIS&T and Society, and Organizational and Institutional Aspects. (DiBiase, DeMers, Johnson, Kemp, Taylor Luck, Plewe & Wentz, 2006) These are further divided into 73 units, 329 topics and over 1600 formal educational objectives, so though the 10 areas may seem broad, they do go into an extensive amount of detail for customisation and application to many disciplinary circumstances and beyond.

3. Methodology - Identifying Research Projects that Employ GIS in an IDR Context

Google Scholar is a search engine, designed and run by Google Inc., to specifically search academic books and articles. To keep track of the prominence of publication sources, Google Scholar keeps and compiles metrics for journals, namely as the h5-index, which is defined as the 5 year median of the h-index, or the largest number h such that at least h articles in that publication were cited at least h times each (Google Inc., 2013). Each journal stored in Google's database will belong to one or more categories, as defined by Google, making up 255 categories in total. Journals are then ranked and sorted by category to identify the top, usually 20, journals, by h5-index, for each category. This thus provides an ideal tool to identify research where GIS has been used in an IDR context.

To identify the relevant publications, a search process was implemented to trawl all the top journals listed for all categories in Google Scholar's metrics, to search by journal, by category, for the first page of results returned and total number of search results returned when searching for "Geographic Information System", "Geographic Information Systems", "GIS", "Geographical Information System" and "Geographical Information Systems" AND "interdisciplinary", "multidisciplinary" or "transdisciplinary". This resulted in a list of the top cited articles from the top journals that self-identify as interdisciplinary, multidisciplinary, or transdisciplinary and use GIS, from which it is possible to address the questions outlined in Section 1. These studies were ultimately what the authors wanted to identify, as they are published in prominent journals and well cited, thus signifying a level of acceptance by the respective disciplines and scholars in the field.

To implement the search, Google Scholar's metrics page was accessed and, for each category (in English), starting with "Business, Economics & Management", the top journals for the category (by their h5-index), were recorded. This was repeated for every category and its subcategories (e.g. subcategories for "Business, Economics & Management" include "Accounting & Taxation", "Economic Policy", "Finance", etc.). An example metrics page is as below (Figure 1):



Publication	h5-index	h5-median
1. NBER Working Papers	161	222
2. The American Economic Review	124	198
3. Review of Financial Studies	111	173
4. The Journal of Finance	103	179
5. CEPR Discussion Papers	100	152
6. Journal of Financial Economics	98	168
7. The Quarterly Journal of Economics	88	175
8. IZA Discussion Papers	81	112
9. Econometrica	72	120

Figure 1. Example of Google Scholar's Metrics Page

For each journal identified by the first search, an advanced Google Scholar search was done for the exact phrase "Geographic Information System", "interdisciplinary" or "multidisciplinary" or "transdisciplinary". An example of the second search is shown in Figure 2:

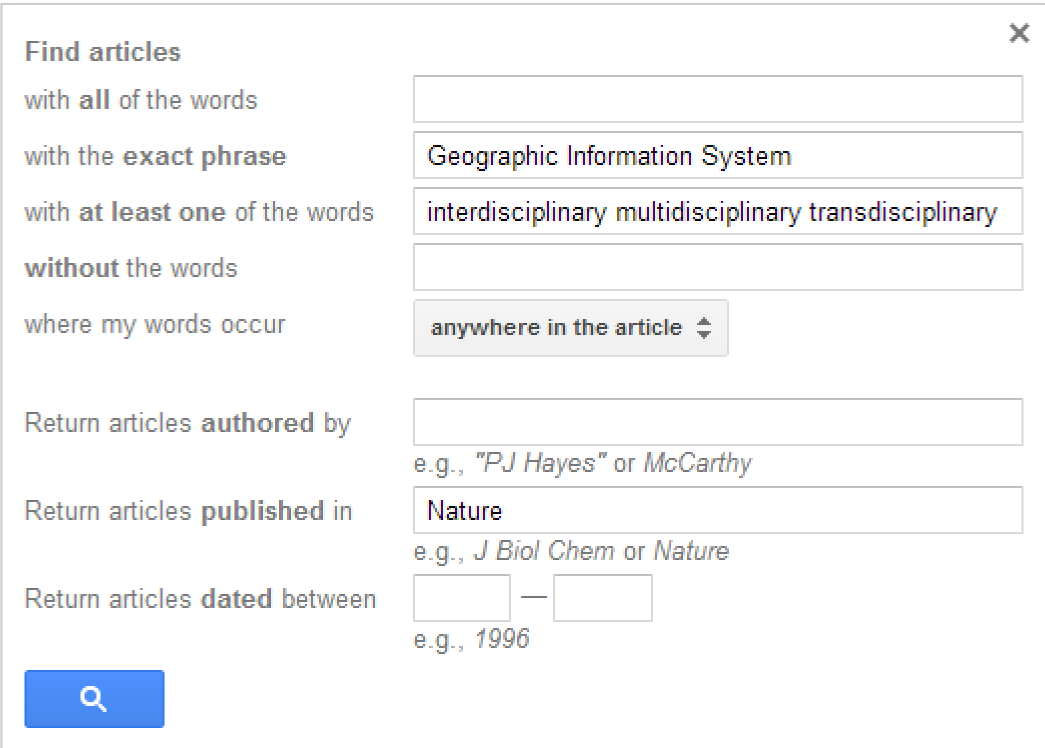


Figure 2. Example of Advanced Google Search Parameters

From the returned search, the total number of results returned from the search result was recorded as well as all the results from the first page, making particular note of the "Cited by" count for each result. An example of the returned search is as follows (Figure 3):


About 41 results (0.07 sec)

Publication: **Nature**

Health Effects of Arsenic Longitudinal Study (HEALS): description of a **multidisciplinary** epidemiologic investigation
H Ahsan, Y Chen, F Parvez, M Argos... - Journal of Exposure ..., 2006 - **nature**.com
... Health Effects of Arsenic Longitudinal Study (HEALS), a **multidisciplinary** and large prospective cohort study in Araihazar, Bangladesh, was established to evaluate the effects of full-dose range **...** **Geographic information system** (GIS) map of HEALS study area and study wells. **...**
Cited by 108 Related articles All 16 versions Cite Save

[PDF] GIS Application In Watershed Management
Y Ma - **Nature** and Science, 2004 - sciencepub.net
... As for a formal definition of GIS, Worboys (1995) defines GIS as follows: A **geographic information system** (GIS) is a computer-based **...** With the concept of **multidisciplinary** integrated approach got an impetus in monitoring and management of resources and environment. Ref. **...**
Cited by 3 Related articles All 4 versions Cite Save More

Figure 3. Example of the Returned Search from the Advanced Google Scholar Search

Following the above searches, all the information was recorded and collated by the original Google Scholar metrics' category/subcategory to derive the top 10 categories/subcategories by total search results for all journals listed as part of the category/subcategory. This was repeated for all selected derivations of GIS ("Geographic Information System", "Geographic Information Systems", "GIS", "Geographical Information System" and "Geographical Information Systems"). Then, sorting the articles by "Cited by" count, for the top 10 categories/subcategories, the primary author then reviewed the top articles to ensure that GIS was actually used in the study, rather than part of the references, captions, etc., or did not have a mistaken meaning (e.g. Gastro-Intestinal System).

4. Results

The results from the initial review are in Table 1.

Analysis of these results has shown that the top cited article, meeting these search criteria, is "Interactions between Groundwater and Surface Water: the State of the Science" (Sophocleous, 2002), from the "Hydrology & Water Resources" subcategory, which was cited 630 times. In contrast, though, "Emergency Management" projects seem to more prominently use GIS, as this subcategory has returned the most search results (254). Though the articles returned are interesting in themselves, the content was also analysed to see if any of the common challenges or proposed solutions in IDR were mentioned in them, to possibly verify the findings of the initial literature review. The tables 2 and 3 list the challenges and solutions, ordered by their importance as derived from the literature review, and the number of articles (of the 10) that make mention of them.

Table 1. Top Cited Articles from Google Scholar Categories with the Most Search Results (Searching "GIS" and "inter/multi/trans-disciplinary")

Category/Subcategory	Number of Search Results Returned for Category	Top Cited Article from Category	Cited by Count
Hydrology & Water Resources	76	"Interactions between Groundwater and Surface Water: the State of the Science" (Sophocleous, 2002)	630
Sustainable Development	82	"Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol" (Sheehan et al, 2003)	392
Remote Sensing	96	"GIS-Based Habitat Modeling Using Logistic Multiple Regression – A Study of the Mt. Graham Red Squirrel" (Pereira & Itami, 1991)	337
Emergency Management	254	"Use of GIS technology in the Prediction and Monitoring of Landslide Hazard" (Carrara et al, 1999)	211
Environmental & Occupational Medicine	33	"Using Geographic Information Systems for Exposure Assessment in Environmental Epidemiology Studies" (Nuckols et al, 2004)	190
Higher Education	220	"Group Project Work and Student-Centred Active Learning: Two Different Experiences" (Livingstone & Lynch, 2000)	116
Water Supply & Treatment	147	"One View of the Future" (Simonovic, 2000)	95
Life Sciences & Earth Sciences	142	"The World of Geography: Visualizing a Knowledge Domain with Cartographic Means" (Skupin, 2004)	61
Fuzzy Systems	105	"A Collaborative Virtual Geographic Environment Based on P2P and Grid Technology" (Zhu et al, 2007)	34
Entrepreneurship & Innovation	92	"e-Government 2015: Exploring m-Government Scenarios, between ICT-Driven Experiments and Citizen-Centric Implications" (Misuraca, 2009)	34

Table 2. Common Challenges and the Number of Top Articles that Mention Them

Common Challenges	**No. Articles**
Difficulties Related to Collaborating with Other Disciplines	**5**
Personal Issues	4
Time Constraints	2
Intransigence from Current Institutional Structures	1
Problems Being at the Interface Between Disciplines	4
Lack of Opportunities for People	0
Licencing and Ownership Ambiguities	1
Lack of Local Level Management	2

Table 3. Proposed Solutions and the Number of Top Articles that Mention Them

Proposed Solutions	**No. Articles**
Provide Training on Technical and Supplemental Skills	6
Build Relationships with Members of the Group	**8**
Include Senior Staff and Interested Parties	2
Incorporate Effective Management Practices to Construct Clear Objectives and Evaluation	2
Increase Funding Opportunities and Adapt Existing Ones for IDR	0
Incentivise IDR with Support and Rewards	1
Establish an Institutional Structure that Prioritises IDR	3
Discourage Disciplinary "Selfishness"	0

Beyond the IDR issues, the articles were also reviewed to see which GIS&T BoK Knowledge Areas' geospatial concepts where part of the studies' analyses. The following lists the Knowledge Areas and the number of articles (of the 10) that make mention of their concepts:

Table 4. GIS&T BoK Knowledge Areas and Number of Top Articles that Mention Their Concepts

GIS&T BoK Knowledge Areas	**No. Articles**
Geospatial Data	**9**
Analytical Methods	8
Data Modeling	7
Cartography and Visualisation	6
Conceptual Foundations	6
Geocomputation	5
Organizational and Institutional Aspects	5
GIS&T and Society	3
Design Aspects	3
Data Manipulation	2

From these results, it can be seen that "Difficulties Related to Collaborating with Other Disciplines" is the most common challenge for all of these studies, "Build Relationships with Members of the Group" is often suggested as the solution and that "Geospatial Data" is the most important Knowledge Area. Also of particular interest is that of all the articles, only half of them had any maps; what was often the case was that the GIS was used to spatially process the data, but then the data were taken into other programs for statistical analyses, as tables and charts seemed to be the desired output from the derived information.

5. Discussion

This work represents a preliminary investigation to pull together a list of published studies, from top journals, as compiled by Google Scholar to find interdisciplinary research projects that used GIS. Comparing against the literature review, an analysis of the articles has verified that “Difficulties Related to Collaborating with Other Disciplines” is a common challenge in practice as well; however, “Build Relationships with Members of the Group” seems to be a more often suggested solution than “Provide Training on Technical and Supplemental Skills”, going against the findings of the literature review. Of particular interest from this analysis, “Emergency Management” studies appear to be publishing the most about IDR that uses GIS, though the top cited article, meeting the analysis’s search criteria was from “Hydrology & Water Resources”. In review of the GIS concepts utilised by these studies, “Geospatial Data” seems to be the most important Knowledge Area (as derived from the GIS&T BoK) for GIS concepts that are relevant to IDR. Importantly, it could also be noted that from the resulting articles, the creation of a map was often secondary to that of simply spatially processing the data.

These preliminary results allow an initial understanding of which interdisciplinary challenges, proposed solutions and GIS concepts may be relevant in practice. The results indicate that, when first establishing an interdisciplinary project, there should be more discussions on and about the disciplines involved in the project – to establish a common vocabulary and understanding together so that disciplinarians can effectively collaborate. Though it may be difficult for universities to offer IDR projects more flexibility with regards to time and money for training and team building exercises, doing so may help solidify the collective aims of the project, accelerate the ability for the team to start producing beneficial outputs, foster future collaborations, and potentially create opportunities to pursue larger, higher-profile funding options for projects with wider scope and greater impact. The congruence between these findings and the literature review for the most common challenge identifies where further efforts should be made to address issues before they arise; however, the proposed solutions differ. Though, studies may believe that “Build Relationships with Members of the Group” is a more viable solution than “Provide Training on Technical and Supplemental Skills”, it could mean that there is a missed opportunity for solving problems in a better way. Perhaps combining both through group learning activities may lead to a more holistic and sustainable solution.

Given the prominent areas that emerged from the articles, perhaps further outreach can be made to “Emergency Management” studies or the other ones as well. Integrating GIS into parts of the curriculum of associated disciplines may help continue to promote its continued successful use. Short courses or certification may be an option for those seeking to learn GIS for continued professional development from these areas that may not have had any formal training prior to. Overall, it can be seen that “Geospatial Data” is an important concept, and so curricula and materials should be tailored to adequately cover this Knowledge Area’s topics. Conversely, this may in itself identify a gap in knowledge, and signify that focus should be on the other Knowledge Areas’ concepts instead, as this one may already be sufficiently understood. As an alternative suggestion, given the wealth of data that was collected, perhaps emphasis should be on attempting to connect with other disciplines that may be those least using GIS in IDR, identified by the lowest returned search results, to establish its relevance and ability to enrich potential analyses.

4. Conclusions and Further Work

Interdisciplinary research is not without its challenges. Many authors have also proposed solutions to these challenges and through an extensive literature review, common ones have been identified that are, often, theoretically suggested. Similarly, core GIS concepts have been proposed and established by Geographic Information Scientists, but those concepts may not necessarily be relevant to those from different disciplines that may wish to use a GIS and the research underpinning this paper highlights both similarities and differences between the material proposed for formal GIS training and that required to permit non-specialists to correctly employ GIS to support their own work.

Further work by the authors will include removing “interdisciplinary”, “multidisciplinary” or “transdisciplinary” from the search criteria, as some studies may not identify as such; analysing further resulting articles for a more holistic understanding of the relevance of the various GIS concepts; and conducting interviews with researchers involved in using GIS in IDR to understand their personal experiences with GIS in this context. From these outcomes, the authors hope to create a short course to teach relevant GIS concepts through a problem based learning approach, to help facilitate the uptake of GIS, pre-emptively handle common issues, and foster interdisciplinary thinking.

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Biography

Patrick Rickles is a full time Research Assistant for the Extreme Citizen Science research group, focusing on bottom-up science with local people, and specialises in GIS Development. He is also a part time PhD student, researching how to expediently teach GIS to those using it on interdisciplinary projects.

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