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Embedding Geomedia as Innovation in the Classroom: A Theory-based Discussion of Innovation Discourse in Educational Systems

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Abstract

Soon after the introduction of Geoinformation (systems) in the 1990s and the first use of geomedia in schools which followed, a host of studies evaluated the adoption of the new technologies at school level. These studies were largely exploratory and descriptive and, even 30 years after its first introduction, came to the conclusion that the use of geomedia in schools was still not widespread. However, an organizational perspective was missing from these studies, as well as analysis of the factors influencing the diffusion of GIS and geomedia.

This paper examines the organizational approaches taken in recent research on digitalization in primary schools and the corresponding teacher training, and looks at questions of diffusion. We attempt to identify the more recent results that seem to make sense of the earlier ones.

Two questions in particular are examined in this paper: To what extent can geomedia be understood as innovation? To what extent are geomedia embedded in schools? We also discuss opportunities for the systematic embedding of geomedia in school education.

Keywords:

GIS, geomedia, diffusion, innovation

1 Introduction

The earliest initiatives in the use of Geographic Information Systems (GIS) in schools can be traced to the 1990s (Audet & Paris, 1997; Strobl & Koller, 1995). Technology at the time was complex to say the least, and much of teachers' energy went into mastering desktop GIS and technology, with literally no supporting pedagogical foundation (Jekel, 2006; Strobl & Koller, 1995). These pedagogical foundations were developed internationally only later, in two main directions: the concept of Spatial Thinking, as put forward by the National Research Council

(2006) and aimed very much at the industrial workforce; the concept of Spatial Citizenship (Gryl & Jekel, 2012), aimed at the critical use of Geomedia[1] in everyday contexts.

Despite considerable and very welcome industry support, namely by ESRI and its local sales representatives, as well as efforts made by trainers of geography teachers across the globe, GIS use in schools remained minimal for years. This situation gave rise to a wide variety of studies that examined barriers to GIS implementations (for an overview, see Kerski (2001, 2003); Baker, Palmer & Kerski (2009); Höhnle, Schubert & Uphues (2011)). Most of them were quantitative in nature, describing criteria for implementation and barriers to it. Second, they did not reflect theoretical approaches to the diffusion and adoption of innovations. Third, none really attempted to formulate a coherent theory of the role of institutions and organizations in the adoption of curricular innovations. Finally, these studies identified the absence of theory around the systematic of implementation of GIS.

In this contribution, we review current research and theory on the adoption of innovations within an education for the digital world in order to reframe older research and draw conclusions for the now changed world of geomedia.

First, we describe how embedding in institutions takes place in order then to frame geomedia as an innovation for organizations (section 2). In section 3, with regard to the implementation of geomedia, we transfer the theoretical framework we have developed to the domain of school education. We examine various factors, identified in recent studies, which might prevent the embedding of geomedia in schools (section 4). Finally, we discuss the Whole-Institution Approach as a new research and implementation framework to integrate innovation in educational contexts (section 5).

2 Diffusion of innovations in institutions

In Geography, the first attempts to look into the diffusion of innovations were those developed in Hägerstrand's (1953) seminal work. However, his work required a broad set of rules which were necessary to calculate the adoption of innovations with the technology of the time (Hägerstrand, 1966, p. 30). These included the spreading of information through personal contact, immediate adoption, and a random mathematical model of adoption. While this was an extraordinary achievement of spatial thinking at the time, it cannot convey the complex decision making of individuals or institutions, or the state-driven curricula for the introduction and adoption of technology in school systems.

2.1 Innovation in educational contexts

Although there have been several attempts to embed first GIS and later geomedia into different learning contexts and subject areas such as *Sachunterricht* in Germany or the Austrian equivalent *GW-Unterricht*, geomedia are still perceived by schools and teachers as innovations.

[1] Geomedia here is used as an umbrella term that includes (usually digital) platforms, tools and artefacts that make use of explicitly spatial references. While most lay persons probably use geomedia, few actively interact with GIS as such.

Innovation is a term used in many different ways and contexts. For the most part, it has economic connotations and comes with a promise of salvation for different segments of society (Briken, 2006). Innovations are changes to the status quo in a system (Heesen, 2009); every innovation is based on a potential for change (Aderhold, 2010). An innovation can be an idea, an activity or an object (Briken, 2006). It is seen as new by the innovators (Karnowski, 2011) and offers greater opportunities for action for the innovators (Haller, 2014). There are also different forms of innovation, such as product or process innovation (Burr, 2004). Product innovations are objects or products that are embedded in an organization; process innovations are reflexive innovations that are aimed at a structural change in the organization (Grey & Gryl, 2024a). The relationship between innovations and innovators can be either reactive (i.e. brought in from the outside) or initiating (developed by the innovators).

However, the meanings of the term innovation are different in the domains of the economy and education (Gryl, 2013). The process of embedding a novelty in an educational organization, such as a school, is discussed by Grey & Gryl (2024b). There are two relevant perspectives here: innovation as an aspect of education, and embedding innovation in the different levels of an educational system. With regard to the former, Grey (2024) distinguishes three facets: innovation as an educational object, as educational potential, and as an educational goal. These facets are inextricably linked. They make it possible to categorize innovations and embed them on the three levels of the education system which we identify in our framework: the macro, meso and micro levels. The macro level concerns the development of national or federal educational policy and laws; the meso level considers the school as a whole unit, which creates its own internal policies; the micro level comprises the teachers, who create lessons (Fend, 2008). An innovation can have educational potential if it requires a change for the system at all three levels, an example of which could be inclusion (Fend, 2008).

Educational objectives are those innovations that become codified goals of education (for example competencies, such as digital literacy, which should be part of school curricula). Accordingly, there are far more innovations that remain educational potentials than become educational objectives. Finally, innovation, or a particular innovation, can itself be the object of education, that is the topic of learning in the classroom (Grey & Gryl, 2022).

The extent to which geomedia and their implementation are innovations for a school organization needs further examination. With regard to the facets of innovation outlined above, geomedia can be described as an innovation that definitely has the potential for change; geomedia are brought to the school reactively, and are a product innovation that has the potential to be a process innovation. At this point, we have to distinguish between two different contexts: those where geomedia are not used (or used only a little), where they can thus be considered an innovation; those contexts where geomedia are already embedded and so not an innovation (Oberrauch, Breitfuss-Horner & Jekel, 2023).

Grey's (2024) three innovation facets (innovation as educational object, potential and goal) need to be linked with actual models of geomedia in educational contexts. Pettig & Gryl (2023), based on Schulze & Gryl (2022), suggest there are three aspects of learning connected with geomedia: learning *with*, learning *about*, and learning *through* geomedia. From our perspective, learning *with* geomedia is part of the daily life of pupils, but learning *about* and learning *through* are not commonly parts of daily life. They are educational goals and should be considered educational objects, as shown in various curriculum documents.

In summary, innovations can be described as new developments that have the potential to change the system within which they are embedded and to alter its scope of action; they can be reactive or initiating; and they can be the goal, potential or object of education (Grey, 2024). Geomedia are an innovation for schools; they need to become embedded in order to offer pupils the opportunity to learn *with*, *about* and *through* them.

2.2 Embedding innovation at different levels of organizations

Embedding innovations such as geomedia in organizations is a lengthy process. In the case of the German education system, it is usually top-down. A curriculum which includes an innovation is developed at the macro level (e.g. ministry for education); the meso level, for example schools, have to create their own policies regarding the innovation; finally, at the micro level, teachers have to deal with the innovation (e.g. decide just how to implement a particular innovation and how to teach the subject of inovation). So teachers are one key factor, which we will focus on later. First, we have to discuss how innovation is diffused or disseminated, that is becomes embedded in an organization.

In his innovation-decision model, Rogers (2003) models how individuals' decisions become embedded. Innovation decisions are based on previous experience with the innovation, the need that the innovation aims to fulfil, the innovativeness of the individual (i.e. their willingness to implement innovations and tendency to innovate), and the norms of the surrounding social system (Karnowski, 2013). According to Rogers (2003), innovations must

- be perceived as advantageous (offer a relative advantage)
- be suitable for the needs and actions of the actors in the organization (compatibility)
- aid, from the actors' point of view, orientation, by making the actions of others perceptible and capable of being used as a reference (observability)
- be understood as an opportunity by trying out (triability)
- not be underestimated with regard to their complexity (complexity)

Based on these factors (discussed further in section 4 below), Rogers develops two outcomes of the innovation decision: adoption or rejection. If enough factors are fulfilled, the innovation will be diffused. There are various ways for innovation decisions to be made: (1) optionally (= individual choice), (2) by collective consensus, (3) authoritatively or hierarchically (Rogers, 2003). These three modes can be mapped to Fend's (2008) micro, meso and macro levels, because the innovation decision processes described so far serve only the actor perspective and assume that the actors involved have choices at these different levels.

An authoritative innovation decision is taken at the macro level of an organization. This level normally sets objectives for the organization and decides which innovation(s) will be included in its objectives. The decision on the macro level has to be realized on the lower (meso and micro) levels. However, each level can make its own innovation decision and is able to reject an innovation or objective.

At the meso level, objectives are determined by definition. Each innovator at this level is also part of the micro level and has the opportunity to decide whether an innovation is embedded in the specific work process or not (decision made 'optionally').

Regarding the innovation facets of educational potential, goal and object, the macro level recognizes only the educational potential of an innovation and sets educational goals. The meso level can do the same for an individual school. On the micro level, teachers can recognize educational potential; they cannot set goals for a system (only for learning processes), but they can use an innovation as an educational object.

Table : Innovation decisions (based on Rogers (2003))

Level and innovation type	Innovation objects	Actor / group of actors	Innovation facet
macro level: hierarchical	national curricula	ministry	educational potential, educational goal
meso level: collective	internal school curriculum	teacher, stakeholder	educational potential, educational goal
micro level: optional	lesson planning	teacher, learner	educational potential, educational object

Within the education system, the macro level consists of various committees and ministries. At this level, an innovation is discovered, taken up as having educational potential, and codified in curricular documents for implementation in schools. Within the micro level teachers have to decide consensually and individually whether an objective that has been set top–down will be part of their working process or not.

Implementation in specific schools is ensured by collective innovation decisions, which result in internal curricula, for example; the educational goal is adapted to the needs of the school. This process is usually carried out by individuals, but the decision is generally made collectively.

Finally, a subject is included in the internal curriculum by the various innovators.

Although the macro and meso levels should guide the planning and implementation of teaching, the decisions at the micro level are crucial for embedding, as the final embedding is carried out at this level. Because actors can behave actively or reactively towards innovation at each of the three levels, the embedding processes can be described as polyvalent.

3 Diffusion of geomedia in schools

The findings of Grey's study (2024) demonstrate that the embedding of geomedia in school contexts is not a straightforward process. Rather, it is one of negotiation that is decided at different levels of the system by different people (see Table 1 above).

With a view to the facets of innovation discussed so far and with recourse to actual curricula, it can be stated that geomedia have so far been recognized as an educational potential at the macro level but have been defined as an educational goal only to a limited extent (Herzig, 2007). However, approaches to the introduction of geomedia differ markedly between German and Austrian school systems. While in Germany there has been a drive to introduce geomedia in curricula such as technology (GGS, 2014, S. 7), Austria has never really included geomedia in school curricula, based mainly on Strobl's (2008) ideas that fully-fledged GIS should be reserved for higher education, while primary and secondary schools should concentrate on online geomedia. Strobl's ideas gave rise to the concept of spatial citizenship, which moved away from a technical perspective of geomedia to a social one (Gryl & Jekel, 2012), later becoming included in the white paper on "Contributions of geography education to the digital world" (HGD, 2020).

The central aspect, which can already be deduced from Table 1, is that the subject matter must be implemented at the meso and micro levels by the schools and teachers. Consequently, diffusion into an organization is always diffusion into the work processes of individuals. From the studies outlined so far, it can further be deduced that embedding by the specific stakeholders in schools has not yet been achieved.

Other factors influencing embedding, especially for geomedia, were identified by Schulze (2021), who investigated the literature in a systematic review. The main difference between Schulze and this paper is the approach. While this paper focusses on the organizational and diffusion factors, Schulze's aim was to find geomedia-specific factors for embedding (i.e. without referring to the connection to implementation studies more broadly). So, both approaches have a similar objective – to identify how implementation works – but they differ in their approach and implications.

Accordingly, geomedia can also be understood here as a potential, but not as an educational object, because embedding is lacking (see Schulze, 2021); and they can certainly be seen as an innovation for schools, but they have yet to be diffused across the board.

4 Factors of resistance to embedding geomedia on schools' meso and micro levels

Discussions to date on embedding innovations are mostly based on the potential of the subject matter and rarely on the factors influencing the embedding. Based on the multi-level model shown in Table 1, questions arise regarding the embedding of an innovation in a school which vary according to the group of people and level.

We will describe factors that prevent the embedding of geomedia on schools' meso and micro levels, because these are the levels that can be changed by agents in schools (at least within

Germany and Austria). The most important factors are Will, Skill and Tools, as well as innovation-related ones such as relative advantage, compatibility, complexity, observability and triability (Rogers, 2003).

Teachers, their will and competency form the basis for embedding geomedia according to the Will-Skill-Tool-Pedagogy model (Knezek & Christensen, 2016), a model which summarizes the main aspects relevant to diffusion (in our case, the diffusion of geomedia). The model analyses the relevance to teachers of a particular innovation and their will to implement it; their ability (Skill) to implement it in connection with their subject; the usefulness of the innovation (Tool) being assessed; and the necessary didactic knowledge to implement it in the classroom (Pedagogy). Analysis of the literature shows that teachers' skills in dealing with digital technologies are rather low, and that teacher training programmes tend to prepare teachers inadequately (Ackeren et al., 2020). At the same time, various studies on computer science education in elementary schools suggest that the relevance of computer science education is assessed as high, but the teachers' own skills in the area are rather low (see e.g. Best, 2020). The will to use, and acceptance of, digital applications seem to be there, but their skills as perceived by the individual teachers themselves are lacking. The didactic knowledge required to integrate geomedia in schools is also inadequate (Atteneder et al., 2022; Herzig, 2007).

In this context, the approach of Rogers (2003), which raises five factors (relative advantage, compatibility, complexity, observability and triability), is also relevant.

Relative advantage

Hoppe & Falk (2004) describe geomedia as an opportunity for effective and sustainable learning processes, as a chance for the learner to develop links to particular everyday experiences. The content and structural design of school lessons can therefore have various advantages.

Geomedia allow the development of active, social, self-directed, context-based and situated learning processes. Furthermore, they offer the opportunity for real-world inquiry and problem-based learning (see e.g. Schulze, 2021). In addition to these general competencies, geomedia lead to specifically geographic competencies such as domain knowledge, and geospatial thinking and problem solving. To these, Vogler et al. (2012, 2018) added the ability to spatially organize and document learning processes, and therefore to use technology beyond disciplinary boundaries.

Compatibility

However, these diverse normative potential advantages need to be weighed up in terms of their compatibility with achieving actual embedding of geomedia in schools. The overall compatibility of an object is measured in terms of various factors. For example, there must be a fit with the learners, with the teacher and the subject (Kattmann et al., 1997). As the teacher usually still monopolizes decision-making and opportunities to act in the classroom, the fit with the teacher and their work processes is of particular interest. At the same time, another factor that arises in almost all school contexts must be considered: the insufficient number of teaching hours. The high amount of time required to embed geomedia in school teaching and learning processes leads to a lack of embedding.

Complexity

For the embedding of an innovation to occur, the advantages and adaptability of the innovation must be rated high, and teachers' perceived complexity of the innovation itself and of embedding it needs to be rather low. Factors that are directly related to this are the objectives, the subject-specific compatibility of an innovation, and the skills required by teachers (Grey, 2024). Against this background, geomedia are frequently considered by teachers to be unsuitable. In particular, they tend to select objects for teaching that they find interesting and feel confident in working with (Rubach & Lazarides, 2021); a teacher may consider a subject complex if they perceive their own skills as insufficient (ibid.).

Only in isolated cases are objectives for geomedia embedded in school curricula at the macro level (Herzig, 2007). Systematic embedding in all curricula is still lacking. The relevance of geomedia to other subjects (such as the humanities), and interdisciplinary and cross-curricular approaches also need to be discussed. In a recent empirical study, Pellinka et al. (2024, p. 4) found that teachers' perceptions of the significance of geomedia in an educational context centred on two main ideas: the idea of a multidisciplinary umbrella concept, and their contribution to critical media literacy. These findings differ markedly from academic descriptions of GI(S) and Geomedia use for spatial thinking as referred to above.

Triability

Particularly important due to the inadequate skills of teachers regarding geomedia is the concept of triability (i.e. the opportunity for teachers to try something out for themselves). If teachers do not master geomedia, if they consider them too complex, there is, however, at least the possibility that they will consider them "triable". One possibility for triability is the use of low-threshold material that enables direct access to geomedia, through which an innovation can be assessed for the feasibility or not of introducing it in the classroom.

There are various platforms for the use of geomedia in schools based on industry-standard products, such as ArcGISonline, Survey 123. Approaches and courses to implement GIS in schools include the Arc GIS Experience Builder (Kerski, 2023). An even lower entrance level is provided by the ESRI Living Atlas (Strobl, 2023), which allows for a thematic and conceptual approach instead of a technical, GIS-centred one (as advocated by Marsh et al. (2007)). Nevertheless, all these programs require adequate skills, which are not currently de rigueur in teacher training curricula across the board.

Observability

Finally, the object must be observable. Teachers must know that other teachers are also using geomedia in order to create a community of practice, for which low-threshold materials can be a useful approach.

To summarize, geomedia are an innovation which is not extensively part of school learning, because of different factors that prevent the implementation on the meso and micro level.

On the meso level, schools need to set up their own geomedia policy and curriculum and to use geomedia as an educational object, which requires potentially new competencies and the will to embed geomedia. Furthermore, there is a need to build up the systematic embedding of innovation on the micro level in educational contexts; geomedia are just one innovation which could and should be part of school lessons. Topics like inclusion, sustainability and so on could be embedded on the micro level as well. In the next section, therefore, we propose a framework for how embedding geomedia or other innovations in schools can be achieved.

5 Towards a new research perspective: Whole-Institution Approach

To enable the embedding of innovation, Grey (2024) proposes the Whole Institution Approach for Digitality, based on the Whole Institution Approach (Buckler & Creech, 2014). This approach aims to bring about a *systematic* change in educational institutions, because the change of individuals alone is insufficient to integrate a structural innovation such as digitality, or a product innovation such as geomedia. Most public institutions have no need to change because, unlike in market-based companies, there is no pressure to innovate (Burr, 2004). A systematic restructuring of institutions is therefore required in order to integrate innovations in the long term. To do this, steps need to be taken on three main levels: structural steps, personal steps, and practical teaching steps.

Potential changes must be identified at the macro level as objectives and codified. These then enable the implementation of innovations at the other levels, and finally the meso level is able to develop its own policy.

The personal aspect, on the micro level, is absolutely key to change, because teachers form the main group in schools and can reject innovations. The embedding of innovation requires a high degree of professional competence and individual willingness on the part of the organization's members. The necessary professional development programmes must therefore be in place to equip teachers with the skills they require. Finally, connectivity needs to be created between appropriate learning opportunities for innovation and teachers' respective subject areas. The aim must be for teachers to use not only technical approaches to geomedia, but also their didactic possibilities.

Accordingly, skills and interest in geomedia need to be generated. The specific fit of geomedia to the teachers' own subject areas must be demonstrated and, finally, cooperation and collegiality must be strengthened. Applied to schools, this means that objectives must be formulated at the macro level which can be linked to various school subjects. One approach could be to create integrative learning opportunities within schools (the meso level) in order to link geomedia to topics in other disciplines (e.g. Vogler et al. 2018). For example, the German subject *Sachunterricht* or the Austrian *GW-Unterricht* could serve as points of reference for using geomedia integratively in disciplines from language studies to history and biology. The better trained the teachers are, the lower the access threshold is, and the better the corresponding teacher training, the more likely such integration could be achieved.

Conclusion

The embedding of geomedia in schools is a structure of processes at different levels in which each level has an effect on the embedding. Accordingly, the discourse needs to be adapted away from the normative claims of embedding towards a systematic discussion of the embedding needs of teachers. Teacher training, the design of low-threshold materials and the formulation of objectives all need to be discussed if teachers are to use – and embrace – geomedia as an educational object. Geomedia need to be seen not only as adding value in science-based teaching, but also as enhancing lesson and pupil management, and their use needs to be adaptable to specific classroom uses and existing lesson plans, across disciplines.

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