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TEACHING GEOGRAPHIC INFORMATION SCIENCE CONCEPTS WITH QGIS AND THE LIVING TEXTBOOK – TOWARDS A SUSTAINABLE AND INCLUSIVE DISTANCE EDUCATION

A. da Silva Mano[1*], P.W.M. Augustijn[2]

[1] University of Twente, ITC - Faculty of Geo-Information Science and Earth Observation, Department of Urban and Regional Planning and Geo-Information Management, the Netherlands - a.dasilvamano@utwente.nl

[2] University of Twente, ITC - Faculty of Geo-Information Science and Earth Observation, Department of Geoinformation Processing, the Netherlands - p.w.m.augustijn@utwente.nl

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ABSTRACT:

In 2020, many students could not travel due to the restrictions imposed by the COVID pandemic. In response, Faculty ITC of the University of Twente offered the online course Principles and Applications of Geographic Information Systems and Earth Observation as the first quartile of a full presential MSc. Programme. The course used the flipped classroom strategy to enhance student's ability to choose the learning strategy that best fitted their learning styles and was developed around four principles: (1) The course was Exercise led - students were introduced to concepts from the exercise descriptions; (2) Every concept taught was demonstrated and operationalized; (3) To emphasize the focus on concept learning, only two software tools were used - QGIS and the Living Textbook; (4) The software tools should be inclusive and encourage technological independence. The first three elements were evaluated by comparing the student feedback, the evaluation questionnaires and the academic attainment levels of the 2020 course with the in-house. The inclusiveness and technological independence were measured via the institutional impact. The results were positive for the new course setup, with students performing slightly better when compared with 2019 in-house edition of the course. The course had a significant institutional impact by contributing to a deeper commitment to open-source software tools. Open source is now the primary choice for teaching, with ITC becoming a QGIS-certified organization.

1. INTRODUCTION

1.1 Institutional context

The Faculty of Geo-Information Science and Earth Observation, also known as ITC, is one of the faculties of the University of Twente, located in Enschede in The Netherlands. ITC was founded in 1950 as an independent institute and became a Faculty of the University of Twente in 2010. Along with education and research, the ITC mission aims at capacity building in geo-information science as a tool to tackle challenging societal problems (Faculty ITC, 2003a). ITC has a rich history of international acknowledgment, the most recent being the very high ranking awarded to ITC by the ARWU Shanghai Ranking (Faculty ITC, 2003b).

1.2 The M-Geo program

One of the study programs offered by ITC is the Master of Science in Geo-information Science and Earth Observation, a two-year course offered in several specializations that reflect specific areas of interest and geo-information application domains (Faculty ITC, 2003c) It is a well-established master ranking as a 'Top Ranking Program' of the Netherlands by the independent advisory organization Centrum Hoger Onderwijs Informatie (Faculty ITC, 2003d).

1.3 Distance Course: Principles and Applications of GIS and RS

Regardless of the student's specialization, the first quartile consists of a joint course that teaches students the fundamental concepts of Geographic Information Science and Remote Sensing, sometimes referred to as the 'Core course'. It consists of 14 EC (European Credits) distributed over three individual courses: Geographic Information Science and Models, Earth Observation, and Data Integration. Most students come from outside Europe. Therefore, quartile one was offered entirely online from 2017 until 2020. This article will focus on the experience of the last iteration of the course – 2020 – as it was also the edition with more students due to the travel restrictions imposed by the COVID pandemic. The online version of the course was named Principles and Applications of Geographic Information Science and Earth Observation' to encapsulate the focus on the conceptual and scientific dimensions of the course.
The course focused on teaching concepts paired with software applications and examples of the concept. The ruling principle of the course is that any concept introduced to the student should be operationalized with examples in pen and paper or software tasks. To facilitate this, the software tools should remain the same along the course as much as possible. The motivation for this requirement is to reduce technological stress as much as possible, a well-documented phenomenon in education (Halupa, 2020; Zauberman, 2003). Greater technological simplicity means more time to focus on learning instead of spending time and energy learning new tools.

In 2020, the course ran with 32 students, representative of 16 nationalities, spread over eight different time zones (Figure 1) - an essential element to consider when planning the two types of synchronous contact hours: interactive video classrooms and chat sessions. Students that followed the course from timezones west of UTC+3 had different contact hours than students from locations to the East of mentioned timezone.

[*] Corresponding author

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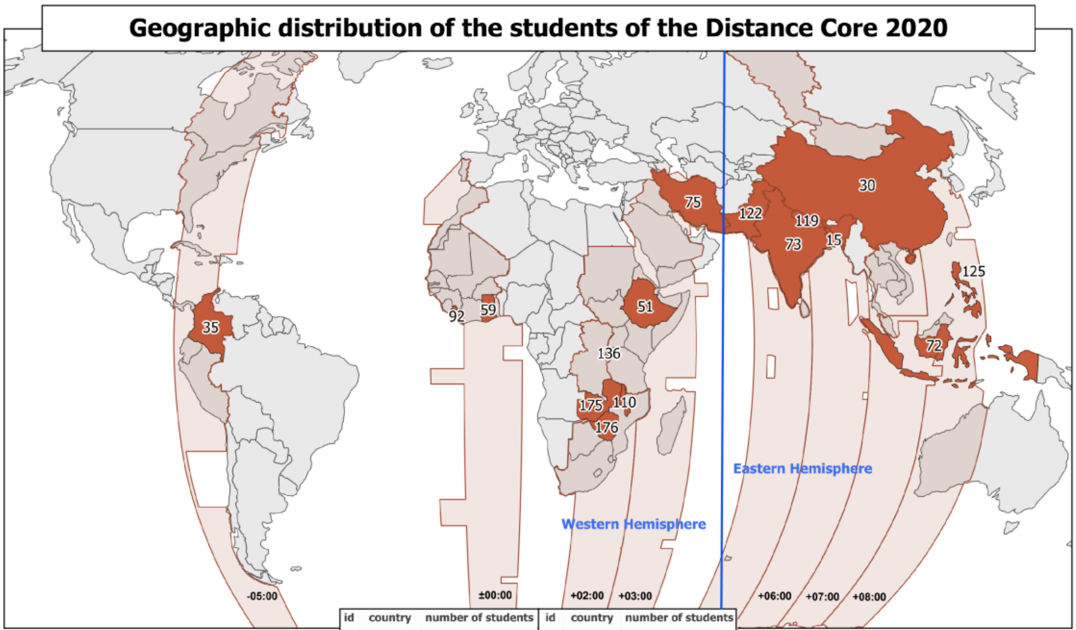

id	country	number of students	id	country	number of students
15	Bangladesh	2	92	Liberia	1
30	China	1	110	Malawi	1
35	Colombia	1	119	Nepal	2
51	Ethiopia	1	122	Pakistan	1
59	Ghana	2	125	Philippines	1
72	Indonesia	1	136	Rwanda	3
73	India	11	175	Zambia	1
75	Iran	1	176	Zimbabwe	2

Figure 1. Student distribution by country.

2. LITERATURE REVIEW

Distance education is a concept older than the Internet (Lee, 2009), but the Internet significantly improved some of the drawbacks of analogic distance education, namely communication and social iteration (Carswell, 2000; Hassan, 2020). With it, several often interchangeable terms were proposed to describe education conducted mainly over the Internet. These include 'Computer enabled education, 'Web-based education, 'e-Learning' and other variants (Anohina-Naumeca, 2005). In our case, we use the term' Distance Education' to designate a course conducted over the Internet where the student is never in physical contact with the teachers or colleagues, in a similar view proposed by other authors (Moore, 2011).

Regardless of its variants, Distance Education has a few didactic challenges. Concerns about the quality of the courseware (Guohong, 2012), lack of attention to soft and transferable skills (Shaytura, 2020), pedagogical appropriateness (Serdyukov, 2015) and the temptation to mimic conventional models in a virtual setting (Nae, 2020) are recurrent amongst educational experts. On the other hand, the potential of distance education to provide learning opportunities and change how we look at education is widely acknowledged (Hollenbeck, 2021). It has gained increased interest as a solution for situations where students are prevented from travelling, like in the recent COVID pandemic (Masalimova, 2022). Furthermore, issues related to inclusiveness and sustainability are also starting to deserve attention (Shaw, 2019).
In the experience described in this article, we try to address some of the challenges of distance education by taking advantage of the flipped classroom model adaptability (Lage, 2000) as the didactic approach and of FOSS4G (Free and Open Source Software for GIS), in particular, QGIS, as the primary teaching tool. The theoretical grounds of the critical decisions taken during the course development are further explained in the latter chapters.

3. COURSE SETUP

3.1 Didactic approach

The distance course was a direct adaptation from its in-house, face-to-face equivalent regarding contents and learning outcomes, albeit the delivery mode was virtual. This meant the didactic approach had to be different. Examples of blended and online learning where the flipped classroom was used (Awidi, 2020; C.C. Hsiao, 2019) encouraged the distance course to adopt the Flipped Classroom approach. This approach reverses the traditional educational arrangement by delivering course content and asking students to move through the materials before the classroom interaction (Virtual Classroom session). This approach encourages the student to be an active learner. However, it also means the student can influence the content of the contact moments, which consist of daily Virtual Classroom sessions of up to two hours. In these sessions, the teacher addresses the students' questions and promotes challenges and brain teasers according to the student's feedback based on what they have read and done as preparation for the session.

This approach aimed to stimulate a proactive attitude from the students – an essential skill in an academic setting. Another benefit is that it can be a more inclusive didactic approach because it is highly adaptive to a student's learning style by not forcing a linear, predetermined order of steps. Every topic within a course consisted of the same number of steps that formed a Learning Unit (LU). Students were free to take some of those steps in any order they wished to accommodate their learning styles better) (Figure 2).

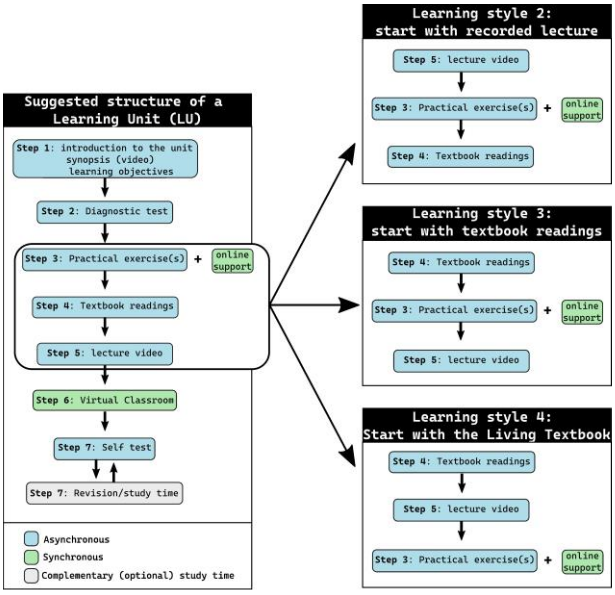

Figure 2. Suggested structure of a LU (right) and the different ways to approach it depending on study styles preferences (left).

3.2 The Living Textbook

Academia and industry emphasize the science and concepts that embody a specific field of knowledge (Stelmaszczuk-Górska, 2020). For this course, a reference textbook was the mandatory reading material (V.A. Tolpekin, 2013). However, a classical PDF Book might not be the best choice for a distance course because it does not reflect the non-linear way learning happens online (Augustijn, 2018).

While addressing the challenges of non-linear study, we sought an approach that would encourage students to explore how concepts relate to each other and also allow students and teachers to make use of learning paths, defined as a sequence of concepts that should be read one after the other to cover a given subject. The result is a Living Textbook consisting of concept definitions taken from the traditional book, each covering one particular concept, organized in the form of a searchable wiki and representable as a concept map (Figure 3).

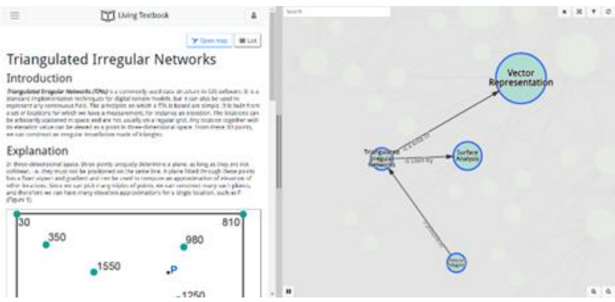

Figure 3. The Living Textbook: the left pane shows the text describing a concept; the right pane the concept map showing the close relationships to the concept described on the left pane.

The conceptualization of the pre-existing textbook is based on ontologies constructed over several discussion sessions held by the teachers responsible for teaching a particular topic. The tool is free to use by everyone, regardless of being a student of ITC (The Living Textbook, n.d). Additional information on the development, user experience feedback, and roadmap of this ongoing effort can be found in RLG Lemmens (2018) and Augustijn (2020).

3.3 Geospatial software: QGIS

A solid theoretical foundation was the main objective of the course. In that sense, operationalizing and demonstrating the concepts taught is vital. It contributes to de-abstracting the concepts, making them more graspable through direct experimentation – a fundamental characteristic of active learning (Wrenn, 2009). We envision a relationship between the tools students use to learn GI Science and the tools they will later use or seek access to when they start their professional careers. The initial investment the learning process represents can induce a software platform dependency, often with financial implications due to license restrictions, which might lead to vendor lock-in situations. Besides the ethical considerations one might elaborate on, such scenarios often prevent those with fewer financial resources from moving forward. This is especially pernicious in capacity building and education, and it is hard to conciliate with UNESCO's Open Science recommendation (UNESCO, 2021) and the European Commission Strategy for Open Source (European Comission, 2020).

Hopefully, from the previous remarks, it becomes clear that the GIS software is not a detail when designing a course. The software choice for the course was QGIS (QGIS Development Team, 2021) for several reasons:

a. QGIS provides the ability to operationalize all the concepts taught in the course in one single software package (either from native functions or by using providers or plugins), thus reducing the technological burden;
b. Being licensed under the terms of the GNU GPL2 license (GNU, 1991) guarantees users independence from restrictive license terms by removing financial and legal barriers to use the software for future projects;
c. QGIS has a vibrant community that represents engagement opportunities outside academia for our students, something ITC encourages;
d. Finally, QGIS is a very active project that has attracted many code contributors, as seen on the project's Github. When developing educational resources, it is an assurance that the educational material can rely on the software in the years to come.

3.4 The courseware

New exercises were developed to embody the principles described to explore the possibilities offered by the Living Textbook and QGIS as the software tool. This courseware explores the active learning symbiosis between theory and practice by populating the exercise descriptions with readings from the textbook whenever a concept is about to be operationalized in the software (Figure 4).

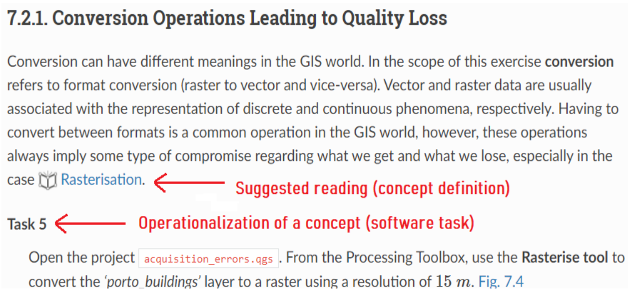

Figure 4. Excerpt from the courseware: example of an exercise description supported by links to relevant readings.

The courseware is written in *reStructeredText (RST)* using Sphinx, a python library with the ability to generate documents in HTML, ePub or PDF format (Figure 5). This approach is also more technologically inclusive because it allows for students with poor internet connections to render a PDF or epub file with the exercise descriptions when starting the course.

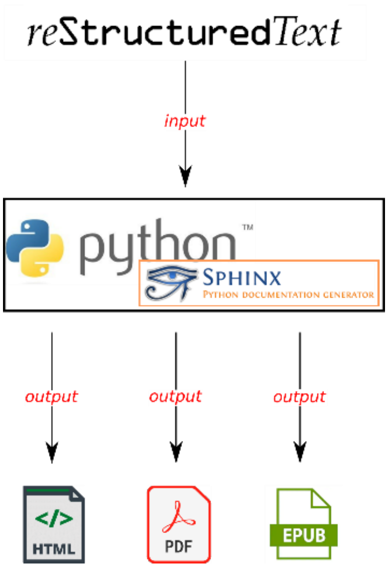

Figure 5. courseware implementation architecture.

4. RESULTS

3.5 Learning outcomes and attainment levels

When evaluating the results, the most important results are those related to attainment levels of the course's learning outcomes expressed in the form of the final marks. A direct comparison is made taking the last in-house edition of the course, which took place in 2019, with the 2020 distance version (Table 1).. Despite similarities in learning outcomes and assessment, the in-house version used proprietary software and didactically used a teacher-led approach. Distance students tend to score higher in most assignments and exams (average final mark of 6.9 and 7.4 for Geographic Information Science and Data Integration courses, compared to 6.5 and 7 in 2019 respectively), except the Earth Observation course (average final mark of 6.5 compared to 7 in 2019), where the in-house students scored better, on average. The reasons for this are not entirely clear. In any case, the results are pretty encouraging, and we regard them as a very positive outcome.

	Geographic Information Science course			Earth Observation course			Data Integration course		
	2019 (in-house)	2020 (distance)	Difference	2019 (in-house)	2020 (distance)	Difference	2019 (in-house)	2020 (distance)	Difference
Exam (65%)	5.6	6.5	0.9	6.1	6	-0.1	6.6	7.4	0.8
Assignment (30%)	5	6.5	1.5	7.7	6.9	-0.8	7	7.3	0.3
Final Mark	6.5	6.9	0.4	7	6.5	-0.5	7	7.4	0.4

Table 1: Average marks attained by the distance course students (32 students) compared with the average marks of the students following the in-house course (110 students). The remaining 5% were assigned to pass/fail activities and are not considered for this comparison.

3.6 Students feedback

Equally important is to look at the students' feedback in the form of course evaluation questions. In this article, we highlight the feedback related to the courseware and software as they provide the relevant information in the context of using FOSS4G in higher education (Figure 6).

Although only 15 out of 32 of the students decided to submit answers to the evaluation questionnaire, the overall impression is that students feel well prepared and are very positive in their appraisal of QGIS (average 3.4 out of 4) and the accompanying courseware.

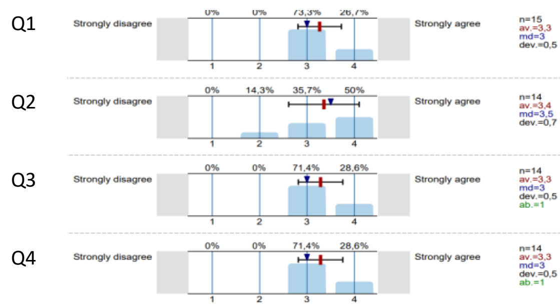

Figure 6. Evaluation questionnaire (subset) Question 1: The platform and the style used to publish the exercises was pleasant and easy to follow Question 2: QGIS was a good choice to help learning the theoretical concepts Question 3: From a practical point of view, I feel well prepared for continuing my studies Question 4: From a theoretical point of view, I feel well prepared for continuing my studies.

Regarding learning styles preferences, it appears clear that the flexible approach offered by the course was used by the students. Except for starting a study unit by watching the

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recorded lecture (64%) there is no clear dominance in study style preferences. (Figure 7).

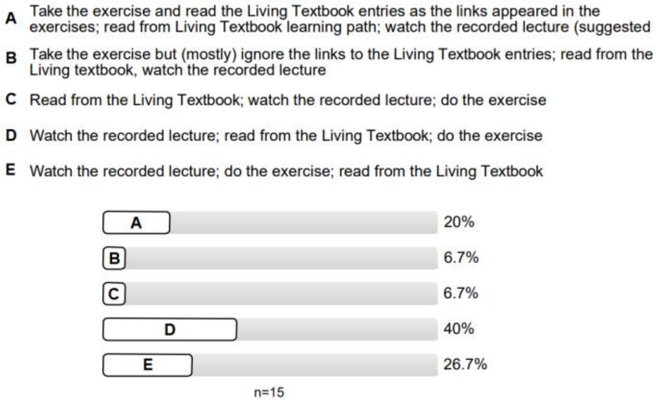

Figure 7. Student's preferred learning styles.

3.7 Institutional impact

Developing a long course using new didactic approaches and tools will have impacts at an institutional level. We classify these impacts in three dimensions: teacher's development, institutional engagement with FOSS4G, and education development strategies.

Teaching in higher education is not the sum of concepts taught. Increasingly, the focus is on transmitting transferable competencies to several application domains (Abykanova, 2016). These typically include critical thinking and problem-solving; GI Science is no exception (Uwe, 2013). Developing a course with new didactic approaches and especially new tools requires the teacher to re-think his/her teaching skills, competencies, and technical and scientific knowledge. During the development and delivery of the course, the teachers involved in the module (15 in total) discovered not only a new tool (QGIS) but also got familiar with the Open source development model, which can be quite different from the proprietary format teachers might be familiar with. This included understanding the development cycle of the software, the community channels and finally, the role of the users as active actors in the development cycle of the software.

The second impact is the institutional engagement with FOSS4G in general and QGIS in particular as the primary tool for teaching GI Science and Earth Observation. The course experience and the good results encouraged a definitive shift towards open source as the preference when it comes to teaching. As of 2021, Quartile 1 of the Master in Geo-information Science and Earth Observation uses QGIS as the preferred GIS software, and ITC successfully applied to become a QGIS-certified organization.

Finally, the whole experience triggered initiatives to develop open educational resources. Discussions related to the development and sustainability of open courseware are well advanced within the Faculty (Konkol, 2021). An immediate result is that both the Living Textbook and courseware developed for the course (Da Silva Mano, 2021) are now offered to the community as open courseware under a permissive Creative Commons License.

4. DISCUSSION

The results shown in Table 1 are, naturally, linked to the critical design principles of the course. One of the course pillars is the assumption that learning, especially in a distance and virtual environment, is not likely linear: the order by which the students take tasks is not necessarily the same order the teacher planned or considered ideal. The greater the flexibility of a course, the more inclusive that course becomes because every human is different, and the logical outcome is that there will be different learning styles

Appraisal for the style and platform used to publish the exercises – the central component of the course (Figure 6), is very positive. It appears to confirm that having a stable learning environment where the style used in the documents remains consistent throughout the course contributes to a successful learning experience, as recent research suggests (Hicks, 2021). Consistent styling allows the students to scan faster through the documents, and its importance should not be underestimated.

Having QGIS as the only software package throughout the course contributes to students staying focused on the contents rather than on the tools. However, other elements deserving discussion are the issues of inclusiveness and sustainability. Using a solid FOSS4G project like QGIS is an element of inclusiveness. It lowers the entry barrier by providing a very liberal license model and having fewer hardware requirements than the primary commercial alternative, therefore reducing the hardware requirements the students are expected to comply with. Another benefit to inclusiveness is that the license model does not restrain the use of QGIS in countries currently under international sanctions.

In addition to the inclusiveness arguments for choosing QGIS, an element of sustainability is an added benefit of mature FOSS4G projects. It is essential to define what sustainability means in the context of software. The Software Sustainability Institute defines sustainability as "[…]the software you use today will be available - and continue to be improved and supported - in the future" (About the Software Sustainability Institute, n.d.), a definition we very much agree with. However, it can be extended following the proposal of Venters et al. (2014) to consider software to be sustainable if it has attributes of availability, integrity, maintainability, reliability and safety, all of which are present in QGIS.

A sustainable software choice has positive impacts on two fronts: the course development side and the student's side. For the first case, it means the effort put into developing a course and accompanying teaching materials will remain valuable and relevant for the years to come; for the latter, it means to be familiar with a tool with few entry barriers that can be used for personal and business development in the years to come.

5. CONCLUSIONS

We regard the whole experience – from design to delivery of the course, as highly positive. Results show that attainment levels for this course are comparable, and even slightly better overall, to attainment levels of a traditional face-to-face course and that student satisfaction is high. The results cannot be detached from the critical choices made during the course planning, namely the didactic approach and the software choices (QGIS). We also notice a positive spin-off in terms of institutional impact – within the Faculty, FOSS4G has become more prominent than ever in education. A more explicit policy and initiatives on open educational resources are also directly benefit from the course experience.

The open educational resources we now make available to the community will be maintained in the years to come because they are based on a sustainable software project, and we are confident they will remain relevant and valuable in the years to come.

Finally, a valuable lesson is to simplify the course tools as much as possible. Prioritize the content over the means, allow the students to have as much time as possible to absorb, reflect, and question instead of jumping from platform to platform to complete assignments.

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