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Designing and testing an inclusive environment for teaching multivariable calculus

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Designing the environment

We designed and developed a learning environment for a course in multivariable analysis addressed at engineering students implemented on the Moodle platform.

The environment integrates the usual text-based lecture material with bidimensional and tridimensional dynamic resources as well as with audiovisual resources into a unique navigable website.

The environment aims at furnishing an innovative, stimulating as well as more inclusive resource for learning multivariable analysis.

The overall research framework is that of Universal Design for Learning which is based on the following three main features

- Engagement (the ‘why’ of learning): Multiple ways for stimulating interest;
- Representation (the ‘what’ of learning): Multiple ways for representing knowledge;
- Action and Expression (the ‘how’ of learning): Multiple ways to express knowledge (CAST, 2018).

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- Engagement (the ‘why’ of learning): Multiple ways for stimulating interest;
- Representation (the ‘what’ of learning): Multiple ways for representing knowledge;
- Action and Expression (the ‘how’ of learning): Multiple ways to express knowledge (CAST, 2018).

The objectives we set to ourselves in designing our learning environment were the following.

- The environment should serve to foster learning within a traditional multivariable analysis course.

- The environment should furthermore serve to foster interest in the course's content.

- Moreover, such environment should be more inclusive than traditional learning material in at least two directions:

    - with respect to students with a learning disability and particularly visually impaired students;

    - with respect to students whose first language is not the one in which the lectures are conducted.

The main innovations of the developed environment are inscribed in the two design principles (which thus aim at rendering such web of relations more accessible and directly visible to the students):

- Such environment aims to be in all effect **a unique website** which the students supposedly are familiar with (as opposed to lecture notes, books, etc.);

- The environment aims to include all the material the students need **in one comprehensive platform** including traditional mathematical-symbolic and textual explanations as well as visual representations and audiovisual material.

The idea behind the development of the environment was inspired by the remark of Martínez-Planell et al. (2015) :

[...] *the learning of multivariable calculus implies "the construction of a web of relations among different concepts"* (p. 81).

Overall, we constructed each subtopic page by keeping in mind the following simple rules which instantiate the design principles set out.

(1) Each time an old concept (or a known procedure, theorem or formula) was employed a link was provided in the text pointing to the exact place (in the same page or in other pages) in which such concept was previously introduced.

(2) Each time a new concept was introduced (as well as an example of a property was provided), we introduced both a visual representation in two dimension (which was usually already present in the original notes of the lecturer) and one dynamic in three dimensions by means of the Geogebra software.

(3) At key conceptual points (as well as before exercises) we introduced audiovisual resources (taken from the website https://www.khanacademy.org/ or from other trusted sources) in order to complement the material.

elearning.unipv.it/course/view.php?id=22

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Attiva modifica

Annunci

Analisi Matematica 2 - II semestre 2021/2022

Il corso si propone di fornire agli Studenti le conoscenze di base del calcolo differenziale e integrale per le funzioni reali o vettoriali di piu' variabili reali, della teoria delle serie e qualche nozione su alcune delle piu' semplici equazioni differenziali ordinarie. Si insistera' sulla comprensione e sull'assimilazione delle definizioni e dei risultati principali, piu' che sulle dimostrazioni (solo alcune di queste saranno svolte in dettaglio). Ampio spazio verra' dato a esempi ed esercizi: alla fine del corso, gli Studenti dovrebbero essere in grado di svolgere, correttamente e senza esitazioni, calcoli elementari riguardanti limiti, derivate, ricerca di massimi minimi, integrali per funzioni di piu' variabili, (compresi integrali curvilinei e di superficie), serie, equazioni differenziali, oltre che possedere, con sicurezza, le principali nozioni teoriche.

Lezioni registrate e materiale didattico a.a. 2020/2021

In questa cartella sono raccolte le lezioni registrate e il materiale didattico del corso tenuto nell'anno accademico 2020/2021

Lezioni registrate e materiale didattico 2020/2021

Lezioni registrate e materiale didattico a.a. 2021/2022

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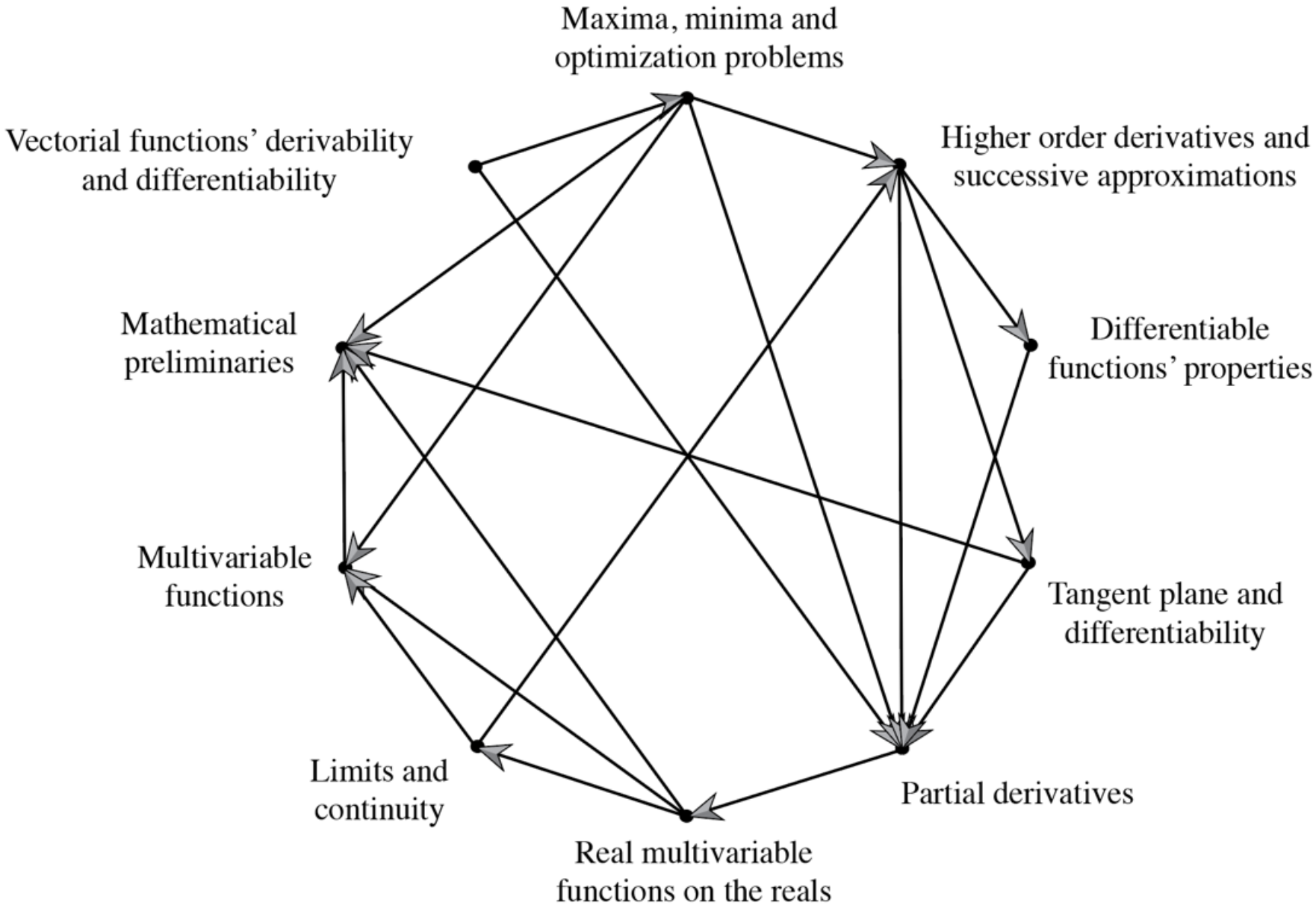
FUNZIONI A PIU' VARIABILI

Le funzioni in più variabili sono discusse nel capitolo 2, paragrafi 1 e 2, e nel capitolo 3 del libro *Analisi Matematica 2* di Bramanti, Pagani, Salsa.

Una funzione $f : A \to B$ è una legge che associa ad ogni elemento di un insieme A uno e un solo elemento dell'insieme B. Nel primo modulo del corso sono state considerate


Maxima, minima and optimization problems
Higher order derivatives and successive approximations
Differentiable functions' properties
Tangent plane and differentiability
Partial derivatives
Real multivariable functions on the reals
Limits and continuity
Multivariable functions
Mathematical preliminaries
Vectorial functions' derivability and differentiability

Testing the efficacy of the environment

In coherence with the EDR framework of research we attempted to test the general objectives that we set to ourselves in designing the described learning environment (cf. Section 3) from different angles.

- On the one hand, for testing whether the environment was effective with respect to the students' learning outcomes we adopted a series of questionnaires which we analyzed quantitatively.

- On the other hand, we adopted a series of interviews which we categorized qualitatively in order to discern if and how the environment was effective in fostering interest in the course's content as well as for observing the environment's potential in being inclusive.

Quantitative test

A mathematical test was administered before and after the intervention to convenience samples taken from the cohort of students to which the digital environment was intended (the experimental population A, 53 individuals) and from a comparable cohort of students (control population B, 75 individuals).

Statistical analysis show that the experimental population (population A) had overall less knowledge about mathematical analysis topics than the control population (population B), but that difference was reduced (for Analysis I topics) at the end of the course. Most importantly, within population A, we noticed better performances (for Analysis II topics) among those who used the materials.

Qualitative interviews

Interviews aimed at qualitatively describe the reasons for adopting (or not) the environment by the students in Civil and Environmental Engineering (population A of the previous quantitative analysis).

Overall, the students of the course at which the environment was addressed (population A) were interviewed by means of semi-structured interviews conducted on a convenience sample: the interviews were realized on the day in which the final examinations for the course took place.

A first question asked if the students used the digital environment provided. If the student say that they did, then a second question followed which asked if, in their opinion, the environment was useful and why (or why not). If the student said that they did not use the environment, a second analogous question followed which asked why did they not employ it.

Qualitative interviews

Overall, 25 students said to have employed the environment, while 39 stated to have not employed it. Among the those who used the environment, 21 students stated that the environment was helpful to them in their study, while 4 said that it was not helpful. Among those who did not use the environment, 8 stated that they did not know about it, while 31 said that they chose not to use it

Furthermore, among the 21 students who stated that the material was helpful, 10 stated that it was specifically because of having everything on one platform which allowed them to concentrate only on one resource rather than having to look at various different resources (textbook, lecture notes, exercises handouts, etc.).

It is nice to have everything in one place without having to go back and forth between materials and books. […]

Qualitative interviews

One of the students, who stated to be subject to a form of visual impairment, said that the material was specifically helpful because he usually employed color change on a Google Chrome browser application while reading.

I use sometimes magnification and change the colors on Chrome […] *this is more difficult if you have the text* [displayed] *on a pdf. It is helpful to have the text on a single webpage* […] *and change the colors.*

Moreover, 7 students stated that what they found primarily helpful were the multimedia resources included in the material. 4 students said that they just generally enjoyed having a video within the notes, while 3 students justified it in terms of the video being in a different language than Italian (which was not their first language). One student (originally coming from North Africa) said

I like to have it [the notes] *in other languages* […] *I often go to the internet to search for material in English or French or Arabic.*

Qualitative interviews

As to the 21 students who willingly did not employ the material 17 said that they did not do so because they preferred or trusted more the textbook or the lecture notes.

After all, the textbook is the textbook, why should I look elsewhere?

Overall, the students' statements confirm the relevance of having all the material in one place (instantiating our first design principle), but for many of them a unique book is as effective as a unique website. For those that appreciated the choices made in the environment (instantiating our second design principle), many addressed the enhanced inclusiveness of such environment both for students with (visual) impairment and for students whose first language is not the same as the lecturer's.

Conclusions

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The quantitative analysius show that the experimental population (population A) had overall less knowledge about mathematical analysis topics than the control population (population B), but that difference was reduced (for Analysis I topics) at the end of the course. Most importantly, within population A, we noticed better performances (for Analysis II topics) among those who used the materials.

The qualitative analysis of the students' interviews evidenced that, among those who adopted the digital environment, many students valued the chosen design principles. The fact that the inclusiveness potential of the environment is recognized, encourages us to adopt these design principles for future similar interventions.

Conclusions

However, the fact that the majority of students was not prone to change the usual textbook for a digital environment, points to the importance of studying students' beliefs about learning materials, leaving an open question for further research. Indeed, more proper care has to be put into advertising the platform to the students and perhaps particularly to the students at difficulty and/or to those who come only sporadically to the lectures. Furthermore, due care has to be paid to explicitly dispel the textbook "aura" (perhaps interiorized by the students in the context of compulsory schooling).

Conclusions

Finally, while the present environment was addressed at engineering students, analogous environments designed following the principles and the implementation rules adopted also have the potential to be employed in other mathematical courses and as addressed to other types of students.

Furthermore, such environments also have the potential to be complemented in various ways by quizzes and forums appearing on the same environment (in the spirit of Gaspar Martins, 2016), given the flexibility of the Moodle platform in this direction. This could serve to enhance the overall learning experience of the students and also to foster further inclusion (with respect in particular to students at difficulty or students who do not attend the lectures or the classroom exercises sessions regularly).

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