DIFFERENTIATED DESIGN: A DESIGN METHOD FOR ILE

Stéphanie Jean-Daubias

Université de Lyon, France
Université Lyon 1 – LIRIS, CNRS, UMR5205
43 bd du 11 novembre 1918, 69622 Villeurbanne Cedex, France

Stephanie.Jean-Daubias@liris.univ-lyon1.fr

Abstract: ILE (Interactive Learning Environment) is a highly multidisciplinary research domain. Design of such systems can not be done exclusively by computer scientists. Educational scientists, teachers who will prescribe the system and learners who will use it should also be involved in ILE design. Management of relationships between on the one hand computer scientists, and on the other hand other members of the design team is not obvious.

We propose a design method, the differentiated design, which aims to ease the management of these relationships by using different design methods adapted to each type of non computer scientist members of the design team.

In this paper, we then present our differentiated design method and show how we applied it in the PÉPITE project.

Keywords: ILE (Interactive Learning Environment), design method, multidisciplinary approach.

INTRODUCTION

In multidisciplinary design projects, computer scientists must work with non-computer scientists members of the team. Relationships between computer scientists and non-computer scientists differ according to the status of the non-computer scientists: they can be researchers, practitioners/prescribers or final users.

This is particularly true for ILE (Interactive Learning Environment) for two reasons. The first reason is linked to the users of the built systems, there are two types of users for ILE: of course *learners*, final users of the system, but also *teachers* who are prescribers for the system and also users all rolled into one. Teachers are users of the system as they use it to do their task (to teach notions to learners) and also because they can also be full final users of the system by preparing its use by learners, by adapting it to their needs and habits, by customising it [8]. The second reason is linked to ILE use: to facilitate integration of systems built in academic research labs to education, it is important, first to work with researchers in education, second to integrate teachers in ILE design [7]. These both points have consequences on ILE design: in the design team, computer scientists have to work with three types of people of different status and competencies, researchers, teachers and learners. Conlon and Pain [2] explain that applied Artificial Intelligence in Education needs "a research methodology that gives a central place to collaboration among teachers, researchers and technologists". In order to help managing relationships between the members of a design team in ILE, we present here the differentiated design method[1], a design method using adapted design methods to each member of the project.

In this paper, we begin to introduce the three design methods we use in our differentiated design method. We then present this differentiated design method. We finally show how we apply it to the PÉPITE project.

DESIGN METHODS

The interdisciplinary design method that we propose uses different design methods. All these methods allow a good integration of the system in the context of use, taking into account in the design process the different members of the interdisciplinary project: researchers, practitioners/prescribers and final users.

In this part, we present the three methods we use: user-centred design, informant design and participatory design. We then propose a synthesis associating to each method, the framework in which we use it in our differentiated design.

USER-CENTRED DESIGN

The principle of user-centred design is to take into account the user in the design of systems [11]. This approach places the user and the task he has to do (when this task is clearly defined) at the centre of the design process.

However, in this approach, relationships between users and designers are limited: users' behaviours are observed, users can be queried about their expectations with regard to the system to build, we can also show them the system built and ask for their opinion. Initiatives are made by designers, not by users.

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1 The work presented here has been initiated during a PhD thesis done at the LIUM Laboratory (Computer science laboratory of the University of Le Mans).

Participatory design

When user's task is not fully defined, user-centred design is not sufficient. In order to define precisely the task, it is necessary to call users, not only to do tests, but also as designers. This process is described by the concept of participatory design [14] [10].

Participatory design process proposes to associate users with the design process from the very beginning of the project: users not only know what they need, but they can also have innovative ideas [3].

This approach let users make initiatives: the user is not only observed and queried, but also integrated in the design process as full designers [10], they give their opinion on the prototype, propose new functionalities, new representations...

Informant design

For works linked with ILE (Interactive Learning Environment), Scaife and Rogers propose an alternative to both previous approaches, with the concept of informant design [13]. They introduce this approach to qualify the design process adopted in the ECOi project, integrating children in the design team. According to the authors, it is indeed difficult to talk about participatory design to qualify design involving children, because children can bring ideas to design, but cannot really be considered as peers by designers. Therefore, informant design can be defined as an approach calling users as informants during design, without restricting them to a passive role, but without consider them either as full partners. Children can for example work with designers on prototypes, but they do not take final decisions.

This design method, build to work with children, can also be used, according to the authors, with other persons, in particular with teachers [13].

Synthesis: differentiated design

The three design approaches we have just presented can be placed along a scale showing the level of the user's participation in the design process (cf. Figure 1). Among these three methods, user-centred design is the approach letting the least space to the user in the design process. Participatory design is the method letting the most space to the user in the design process. Informant design has an intermediary place for the role given to users in the design.

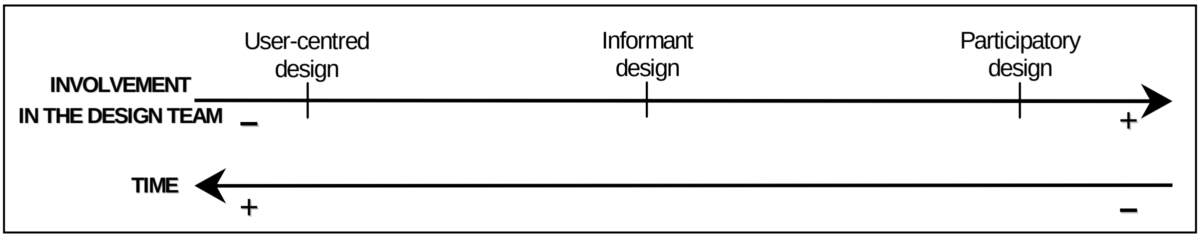

***Figure 1:* Different design methods depending on the level of members' participation in the design team.**

An ILE has several types of users and various types of persons can be involved in its design: students as final users of the system; teachers as prescribers (they chose the system to use) or/and secondary users (they eventually customize the system in order to adapt it to their pedagogical habits); and researchers (educational scientists) as prescribers of the system for teachers.

The differentiated design proposes to use design methods adapted to each type of users of an ILE: user-centred design with final users, informant design with practitioners or prescribers and participatory design with researchers. The use of adapted design methods make easier relationships in the interdisciplinary team, specifying the role of each member of the project and giving each member a role adapted to his possibilities and to the importance of his position in final choices.

The idea is firstly that computer scientists designers can not have the same relationships with students, teachers or researchers and secondly that the different non computer scientists members of the design team can not have as much importance and responsibilities in the project as computer scientists designers. Researchers have to be highly implicated by participating to the design choices. Teachers, as prescribers or secondary users, should also participate to the design so that their practices and opinions can be taken into account. As far as learners are concerned, whereas their needs must be taken into account, whereas it is very important to test the software with them, it is neither necessary nor desirable to integrate them in the design team. Mostly, various types of members of the design team can be involved in the design of the same system. In such cases, in order to refine gradually the importance of changes to make in the system, it is preferable to begin with participatory design (which could produce the more changes in the design) and to end with user-centred design (which consists more in testing the system than in proposing new functionalities).

In the following part of this paper, we develop these various relationships between computer scientists and others participants of the design team of an ILE with an example of use of the differentiated design in the PÉPITE project.

Implementation of the differentiated design in the PÉPITE project

The differentiated design method was perfect within the framework of the PÉPITE project, an interdisciplinary project in computer science and didactics. We present here how we used the differentiated design method in this project, after a short presentation of the PÉPITE project.

The PÉPITE project

The PÉPITE project aims at building an environment able to help teachers in assessing students' competencies in elementary algebra. This research is linked to Interactive Learning Environment researches and concerns more precisely diagnosis of students' competencies [7].

In this project, we chose to reuse an existing validated didactical expertise [4]. This research by Brigitte Grugeon, educational scientists and former teacher gives a support of both teachers and researchers. Using a didactical tool enables us, not only to match teachers' expectations, but also to have a solid didactical basis to build students' profiles. Our work partly consisted in automating this available pencil and paper didactical tool. That is why our project is highly interdisciplinary: at numerous steps of the project, in order to automate the pencil and paper tool, computer scientists and educational scientists must work together.

The built system (cf. Figure 2), called PÉPITE, consists of three parts: PépiTest, the student software proposes exercises to students and gathers their answers. PépiDiag, the diagnosis module, analyses these answers. Finally, PépiProfil concerns teachers, it sets up students' profile and presents them to users (teachers or researchers).

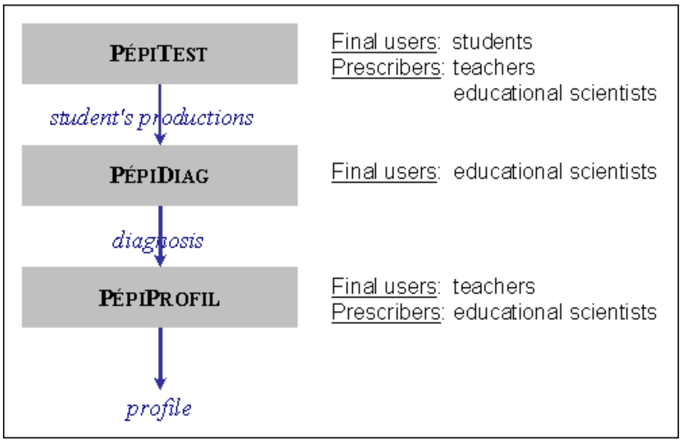

Figure 2: PÉPITE's architecture, final users and prescribers of each module.

Figure 2 shows for each part of PÉPITE, final users and prescribers. PÉPITEST is aimed at students as final users by proposing them exercises to solve. Teachers are prescribers for this system in the sense that they choose to use or not this tool in their classes. At least, educational researchers are also prescribers, but prescribers for teachers and not students. As regards PÉPIDIAG, it is only aimed at educational researchers: as final users, they can use the very fine description of students' knowledge given by PÉPIDIAG to evaluate the didactical tool and to make it evolve. PÉPIPROFIL concerns teachers as final users. Researchers are prescribers of PÉPIPROFIL for them, as they are for PÉPITEST.

THE DESIGN TEAM

Interactive Learning Environments (ILE) is the intersection between various fields: computer science, didactics, educational science, cognitive science, etc. In this interdisciplinary domain, depending on works, some disciplines are used only in order to bring concepts or methods to other disciplines, in that case, it is a multidisciplinary work. In other cases, disciplines work really together (Artificial Intelligent and didactics for example), as to define shared issues (such as learning with computers), shared concepts (such as the concept of computational transposition[2]) and shared publications (the book "Didactique et intelligence artificielle"[3], coordinated by Nicolas BALACHEFF and Martial VIVET is the best example en France). In that context, ILE is an interdisciplinary domain.

Let us precise definitions of cooperation and collaboration highlighting their differences [9][7]. In cooperation, tasks are different, each part of the team (the computer science part and the non-computer science one) makes his part of the work. In collaboration, tasks are shared, participants work together on the same tasks.

Interdisciplinary approach is an essential point of the PÉPITE project. Computer scientists, but also educational scientists and teachers are deeply involved in this project. The work with educational scientists could not only consists in mutual borrowing of expertise. To have a real collaboration, enabling us to work really together, in PÉPITE project we had to learn and adapt the concepts, methods and issues of both disciplines (computer science and educational science) to our needs.

In PÉPITE, work could be considered as cooperation between computer scientists and educational scientists, where educational scientists provide a tool and where computer scientists automate it. Nevertheless, work is not as sequential and segmented as it seems. Whereas the pencil and paper tool has originally been built only by the educational scientists, the automation was collaborative, even if sometimes, certain tasks had to be done cooperatively (for example: educational scientists had to specify terms to use and computer scientists had to build the interface). The interdisciplinary

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[2] Concept describing the transformation undergone by the knowledge when it is putted on a computer (the knowledge taught in a classic learning context is not the same as the knowledge taught with a computer).

3 Didactics and Artificial Intelligence.

approach in the PÉPITE project is not just a cooperation in terms of expertise: computer science do not only serve didactics in order to transform a research tool into a tool usable by teachers, and didactics not only give an expertise to computer scientists, parts of the system have been built collaboratively.

Computer scientists' work had consequences on educational scientists' one. For example, the first prototype proposed by the computer scientists affected the design of a new version of the pencil and paper tool done by the educational scientists. As regards the design of the automated version of the test, the work was really collaborative between computer scientists and educational scientists: they worked together during regular interdisciplinary working sessions. Concerning PÉPITEST, the student software, but even more concerning PÉPIPROFIL, the teacher software (because in this module, educational researchers and teachers are not only customers or prescribers, but also users of the system), design decisions have been taken during such sessions. During interdisciplinary sessions members of the team worked with printed screen shots of the done prototypes. They critically analysed these prototypes, discussed the modifications to do and proposed new implementations. As noted by Nicolas VAN LABEKE about a design involving teachers, "the evolution of the visible behaviour of the software is the only valid progress criterion for teachers – authors"[4] [15]. For this reason, meetings took place when the interface had evolved enough to enable interesting exchanges between computer scientists and educational scientists.

The experimentation of the built systems and the analyse of the gathered data are other examples of collaborative work between computer scientists and educational scientists.

We can take JACQUET, NICOLLE and ANDRÈS's conclusion in our own name: multidisciplinary approach in our project is a "constructive interaction between disciplines without having some taking the place of others and without having some serving others"[4] [5].

CONLON and PAIN use the expression *persistent collaboration* to qualify a collaborative work with teachers and students that do not stop at first steps of the design but go on after the software achievement [2]. This approach mixes action research and user centred design. In our work, we add the work with educational researchers to this approach.

We can also use CONLON and PAIN's concept of persistent collaboration in the PÉPITE project: collaboration between computer scientists, educational researchers and teachers exists all along the design of the different parts of the system and also during the integration into education.

AN INTERDISCIPLINARY COLLABORATION

The definitions we have presented and the characterisation of interdisciplinary approach artificial intelligence / psychology described by Jacquet, Nicolle and Andrès [5], allow us to present in Figure 3 a multidisciplinary / interdisciplinary approach scale which goes from exchange of concepts and methods to the specification of shared projects.

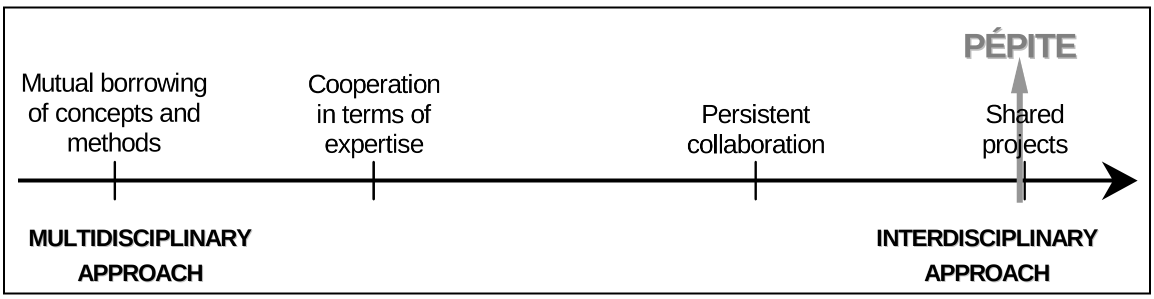

Figure 3: Different types of works put on a multidisciplinary / interdisciplinary approach scale.

4 Free translation.

To place the PÉPITE project on this scale (cf. Figure 3), we can say that the PÉPITE project is an interdisciplinary project as it is, we have seen it in the previous part, a persistent collaboration between educational scientists and computer scientists, with taking over of concepts, methods and issues of the associated discipline. This project is also in an issue shared by computer science and educational science (students' knowledge modelling and integration to education) and uses concepts shared by both disciplines. This is why we placed the PÉPITE project among shared projects in Figure 3's scale.

PÉPITE AND THE DIFFERENTIATED DESIGN

We apply our differentiated design method to the PÉPITE project. It is interesting to apply this design method to this project as it is an interdisciplinary project in which we worked with educational scientists, with teachers and with students. Our relationships with the different members of the project could not be the same with everyone at the same time. The differentiated design method allows us to find an appropriate way to communicate with each members of the project, at the each period of the project.

USER-CENTRED DESIGN WITH STUDENTS

For PÉPITEST, the student system, we have adopted a user-centred design with students, who are final users of the software. The task analysis was given by the didactical analysis. We completed it by a study of pencil and paper corpora that we had for each exercise (500 pencil and paper students' answers, corresponding to PÉPITEST exercises). Study of exercises and students' answers helped us to identify students' needs, particularly to produce their answers: which functionalities should be included in the system? We also called students on several occasions and at different steps of the design to test the usability of the system. It allows us to see how they produce their answers (of which include totally opened questions and algebraic expressions), how they use the proposed functionalities…

INFORMANT DESIGN WITH TEACHERS

For PÉPITEST we also worked with teachers. Our approach was close to informant design with teachers for PÉPITEST, the student software for which they are prescribers. This design method was above all used in the PÉPITE project for PÉPIPROFIL, the software for which teachers are final users.

In both cases, our exchanges with teachers for the design consisted mostly in working on screen shots of prototypes (even if we sometimes worked directly with the prototype) making a critical analysis of them and discussing about the changes to do. Teachers gave their opinion on the presented systems, asked questions about their way of functioning, highlighting points to be clarified and proposing new functionalities corresponding to their habits. However, they did not participate in final decisions, but we always seriously consider their remarks.

PARTICIPATORY DESIGN WITH EDUCATIONAL SCIENTISTS

Our approach was participative with educational scientists, with PÉPITEST, PÉPIDIAG and with PÉPIPROFIL. Educational scientists were for us, on the one hand clients of the whole system, and on the other hand, representatives of the users: students for PÉPITEST (as they study students' behaviour) and teachers for PÉPIPROFIL (as prescribers). In our interdisciplinary design method, we really integrated educational scientists in our design team (as designers). Computer scientists and educational scientists mainly communicate by means of screen shots of prototypes (or diagram before any prototype was done). Exchanges, remarks and ideas of changes were richer around annotable documents. Educational scientists worked easier with this paper than directly with the software on the screen. The software is perceived as something locked, impossible to modify. Exchanges concerned for example terms to be used, knowledge representation at the students' interface, functionalities to implement. Design choices were done during interdisciplinary meetings with educational scientists and computer scientists.

Summary

By choosing design methods according to the kind of person computer scientists are working with, we apply our differentiated design method to the design of the three parts of PÉPITE.

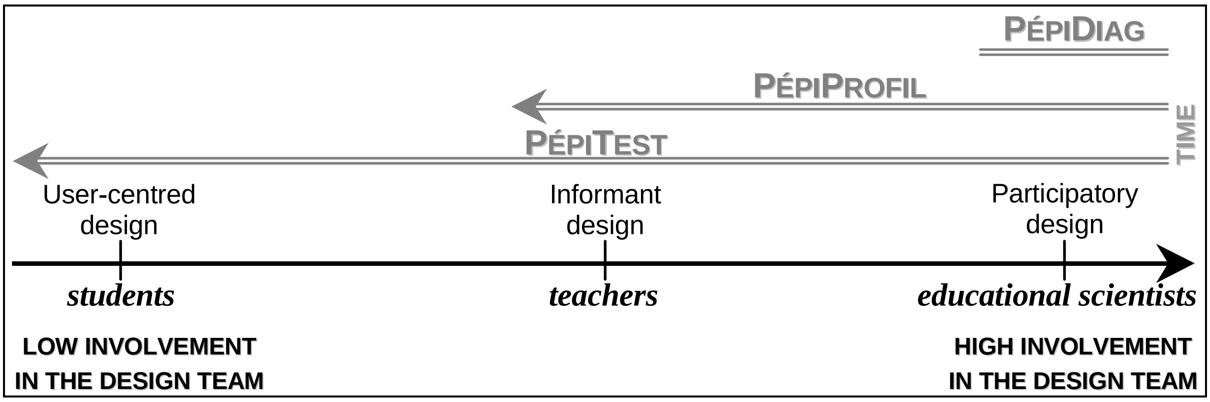

Figure 4: **Different design methods depending on the level of members' participation in the design team.**

Figure 4 shows for each of these parts, the design method and the members of the multidisciplinary team concerned. So PÉPITEST's design required the use of three design methods: user-centred design with students / finals users, informant design with teachers / prescribers and participatory design with educational scientists / researchers, which are clients and representatives of the users. PÉPIPROFIL concerns only teachers, the design of this part required only two design methods: informant design with teachers / final users and participatory design with educational scientists. As for PÉPIDIAG, the diagnosis part of PÉPITE, it does not have any interface and does not directly concerns the different final users of PÉPITE: neither students nor teachers. The design of this part was therefore only done with educational scientists in a participative way.

The design method also guided us in managing the various "types of persons" according to the time when various types of persons were involved in one system. Let us take the example of PÉPITEST, which involved educational scientists, teachers and students: we began with participatory design with educational scientists, then we used informant design with teachers and finally, user-centred-design with students. Main idea is that it is no use testing the software with students if educational scientists (which are prescribers) want major changes.

Our differentiated design method allow us to adapt our approach for the different parts of PÉPITE according to the concerned persons, working with each member of the interdisciplinary design team at the appropriate time using the adapted way of communication.

Conclusion

In this paper, we present an interdisciplinary design method that allows specifying relationships between computer scientists' designers and other persons working in the design team.

We described our differentiated design method and the different design methods it uses. We have also shown how we have applied this method to the design of an ILE with the example of the PÉPITE project.

As a conclusion, we can say that if this design method is particularly adapted to ILE design, it can also be used in any interdisciplinary project involving in addition to computer scientists, different types of persons: users, prescribers / practitioners and researchers.

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