Designing an information system: lessons learnt from an interdisciplinary teaching situation.

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DESIGNING AN INFORMATION SYSTEM: LESSONS LEARNT FROM AN INTERDISCIPLINARY TEACHING SITUATION

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Abstract

This work has been done by crossing two research fields: educational studies and industrial engineering. This paper focuses on a case study of an interdisciplinary teaching which is part of a graduate vocational training (bachelor level). The defined pedagogical sequence aims at improving the students' capacity to reuse some knowledge in the domains of Information System and Operations management that they learnt in different previous teaching modules. We analyse the content and the organisation of the sequence, the students' activity and difficulties and the teacher's role during the class meetings.

Keywords

Graduate vocational training; cooperative education; interdisciplinary teaching; knowledge transfer; information system.

1 Introduction

Today, globalization and technological innovations call for improved organizational adaptability and more flexible and advanced systems relative to manufacturing, logistics, engineering, information and process technology [1]. As highlighted by A.Y. Nahm et al. [2], manufacturer operating in this so called post-industrial environment focus on customers. Their organizational structure has shift from functional multiple-level hierarchy organization to cross functional orientation, with concurrent information flows and decision making, and relatively few layers in hierarchy.

To better achieve this customer orientation and transverse organization, the concepts of Supply Chain (SC) and Supply Chain management (SCM) have been developed in companies' environment, as well as in research field. In a broad sense, a supply chain consists in two or more independent organizations also named inter-organizational or intra-organizational supply chain (in case of a

large company with several sites) [3]. As firms moved towards business process rather than departmental applications, the need to integrate functionalities is increasing: various functions (Shop floor, inventory, advanced planning applications, human resources, etc.) need to communicate so that companies can make accurate promises to customers, and executives can decide more quickly. Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes [4].

For many companies, ERP (Enterprise Resource Planning) is considered as a good answer to replace the fragmented back-office systems and to manage and integrate cross functional business processes. ERP is standardized software that attempt to put together all departments and functions across a company onto a single information system using one unique database [5]. As mentioned by Umble et al. [6], ERP provides two major benefits that do not exist in non-integrated departmental systems: (1) a unified enterprise view of business; (2) an enterprise database where all business transactions are entered, recorded, processed, monitored, and reported. This unified view increases the requirement for, and the extend of, interdepartmental cooperation and coordination. One of the major critical success factors highlighted during ERP implementation is the organizational change management. ERP project has to be managed as Business Process Reengineering project that shakes up the whole organization. They are typically a novel application for the organization that requires a broad base of knowledge in terms of systems and organizational functions [7]

The challenge now in student training in the domains of SCM, logistics and Operation Management, is not to give them strong knowledge in Information System Modeling, no more to train good systems analysts or programmers. The goal now is to make them understand these new challenges in Information System Implementation and to make them realize the role of business process integration, the importance of collaboration between department rather than organizational silos and the need for information exchange and transparency.

According to us, this goal needs 2 training steps:

- First to acquire knowledge in different fields, such as Enterprise organization (department, hierarchy, control and management), Business Process, Best Practices in their domain (Logistic, operation management, etc.), Information Systems, and so on. These types of knowledge are generally acquired from independent and specific training modules of a vocational training;
- Second, to face and solve complex problems, where it is necessary to use at the same time these different types of knowledge learned before

Our hypothesis, based on numerous research results in psychology about knowledge transfer, relies on the importance to built specific teaching situations that lead students to gather together the different knowledge learned before in different teaching settings. When students face alone complex problems in real professional situations, they often have big difficulties in using and articulating different knowledge taught previously. Trainers have to take care about this and imagine pedagogical means to help students.

In this paper, we present a case study of an interdisciplinary sequence which fits into the described pedagogical characteristics. In the followings steps, we present first the general organisation of this teaching sequence and analyse the different types of knowledge that the students have to use to solve the problem set by the teacher. Second we explain our theoretical framework and our methodology. Third we give results of a detailed analysis done from the case-study. In the last step, we discuss these results.

2 General organisation of the pedagogical sequence

The sequence (32h) is scheduled at the end of a 2 years long vocational training (bachelor level), in the operation management domain. This training is organised in a cooperative education form, which means that students alternate professional period in a company and teaching period at the university. The sequence is a part of a teaching module that aims at training students in industrial project management. A part of this module is especially dedicated to the use of modelling methods to design information systems in the context of production management. To achieve this goal, the teacher has developed an original course which objective is not to bring to students new concepts or new methods, but to lead them to activate their own knowledge, already acquired during their studies at the university period or during their professional activity period in a the company.

From a long interview with the teacher in charge of this training, we first acquire some knowledge about his teaching sequences organisation.

First of all, the teacher asks the students to develop from scratch the information system of a fictive company. He gives them only few elements about this company: manufactured products, size of the company, and so on. The students have to work following 4 steps previously defined by the teacher:
1) Creation of a company's organisation;
2) Definition of the information used and exchanged between the different functions of the company;
3) Elaboration of the integrated management system (documents and procedures);

4) Finally, simulation of their fictive company structured on their defined organisation and using their Information System, by the way of a pedagogical game.

During teaching sessions, which last 2 or 4 hours, students have sometimes general discussions all together; sometimes they have to work in smaller groups. Within the interview, the teacher explained us his various roles during the sessions: to give instructions to students; to validate intermediate results, in particular those which are necessary to go to the next step; to motivate and encourage students in using some concepts and methods; to help them to find concepts, methods to solve the problem.

The main principle of the sequence is not to take students by the hand to solve their problem, but to leave them as far as possible using the methods and the resources they need.

3 A priori analysis of the first step

The case study described in this paper deals more precisely with the first step of the sequence. During this first step, students have to create the company's organization. The teacher does not ask them to precisely define all the organization, but to identify the main "parts" directly linked to manufacturing function. He gives only few elements about the company's organization: manufacturing products are mechanical components; the number of employees is about 70; some products are made to stock and others are made to order. To reach their goal, students have to combine 3 approaches about the companies organization: functions; business process; and domain of responsibility. Lorino [8] gives a clear distinction between these 3 approaches.

*« **A business process** is made of different activities linked by significant information or material flows (flow of the products in a factory is a material flow, but this materiality support some information), which combination allows important output. The manufacturing process (output = manufactured products* […]*; the demand management and order delivery process (output = closed customer order) are different examples of business process* […] ***Functions*** *put together similar activities, in terms of tasks or competences needed to do theses tasks. For example, the human resources function gathers all the activities which need knowledge and skills about human resources management, however their localisation in the organisation.* ***Domains of responsibility*** *put together activities entrusted to a same manager; however is the diversity of these activities. Unlike process and functions, they appear in the organisation chart* [as department] *"*

First, students have do define the functions that are necessary to provide a good running to the company. Second, in order to check that all the functions have

been listed, they have to detail the business process (as a succession of activities) which starts from a customer order and ends when the product is delivered. Third, after simulating this process, the students can distribute all the identified activities among the different functions, and then, evaluate if some functions are missing or useless. Fourthly, they can define some departments which will have the responsibility to carry out one or several functions,.

It is interesting to know where and when these 3 concepts (function, business process, and, domain of responsibility) have been taught to the students. We found that 2 teaching modules are more precisely concerned: Module 14 which deals with "stock management" and Module 32 which presents "quality control and management".

Module 14 is one of the first teaching modules taught to the students at the beginning of the first year. This explains why the teacher presents some basic organisational notions like functions and departments. He clearly distinguishes these 2 notions in his lesson: *"We have seen that a company aims at producing by transforming raw materials into products or needs into services, by means of functions distributed into different departments. Depending on the height of the company this distribution can be very different. Functions are named by using verbs of action : to plan the production ; to manage human resources* […] *"*

Module 32 is dedicated to Quality Management (included tools for Quality Management). The teacher explains to the students the difference between the 1994 version and the 2000 version of the ISO 9000 norms. One of the main differences between these 2 versions is the obligation, in the 2000 version, to model the organisation through different business processes. But, the teacher told us that he gives just a brief explanation to the students about that point. Students hear again about *business process* further in the same teaching module, when they have to model a process from a case study, by using a software tool.

This quick a priori analysis shows that students have to use specific concepts and methods previously taught in 2 teaching modules to be able to define the organisation of the firm. They have to distinguish clearly the notions of function, business process and department and to be able to articulate them in a same solving process.

4 Theoretical framework and methodology

To define our theoretical framework, we studied first the numerous works about learning transfer in psychology. Most of the researches done in this domain agreed on one point: knowledge learned in a first situation is hardly transferred to a second one and this is a rare psychological process. Explanation about this human difficulty depends on the theoretical framework that has been used.

- For the cognitivist approaches, the explanation must be found in the human natural tendency to perceive superficial features of problems before their deeper structures.
- Situated cognition gives another explanation: Knowledge emerges in a particular physical, cultural and social context. When it is transferred to another context, it looses its meaningfulness and its pertinence.

According to some research results, it is possible to improve significantly the transfer rate, for instance when people are trained to use concepts instead procedures or to apply the same cognitive resources in various context, but improvements are limited [9] [10].

Most of these researches have important methodological limits, which restraints their capacity to explain what is going on in natural situations [10]. The most important one is that the persons studied in these experiments have nothing else than their memory to solve the problem. In everyday life, people can use different material and cognitive artefacts to solve problems. People can also be helped by others to do some tasks.

Another way to think about transfer is possible by using *Activity theory* [11] [12] [13]. It is an interesting theory because it changes the point of view about the research object which is no more the single cognitive subject, but an activity that includes not only people's thoughts and actions, but also others people, material and symbolic artefacts used during this activity. In this alternative theory, difficulties to transfer are due to the strong human tendency to use only the resources present in the activity system in progress. People do this way both because the meaning of their actions is very related to the mobile of the activity and because the collective routines and rules constituted gradually within the activity system tend to isolate it from others activity systems. Then it can be very difficult for an individual to exceed these rules and these routines to introduce new ways of thinking or acting. However, this theoretical approach considers that transfer is possible and even can be improved by using *boundary objects* (material, symbolic artefacts) or boundary actors which are means to link two or several activity systems. Moreover, one can build an activity system whose finality is precisely to support the transfer between two or several systems of activity.

In our research, we postulate that the students are engaged in various activity systems: each training module is an activity system with its own finality (to teach and learn such disciplinary field), its resources, its places, its routines and its social organization. In the same way, each student is engaged in one or more other activity systems in his company [13]. Through this approach, we were able to modelise the studied interdisciplinary teaching sequence as an activity system with the followings features:

- The mobile of the activity is to reach the teaching objective described above;
- The resources that can be used for acting are concepts, methods, know-how, skills taught or learned before in others activity systems;
- The rules and the specific roles during the activity are the general roles and rules defined by the school and some specific roles and rules defined by the teacher who manage the teaching sequence.

Then our research issues were : (1) to infer the different fields of knowledge that students used to solve this problem and where they acquired it (a previous teaching module and if yes, which one, or from their own job experience in a company); (2) to identify and understand the difficulties the students have, to define a model of the organization; (3) to describe and analyse the role of the teacher in the animation of this innovative teaching situation, especially his role as a boundary actor between different activity systems.

5 Methodology

The research methodology has consisted in observing and analyzing how students collaborate in the group to achieve the first step of the sequence: creation of the organization of the company. We made a video of the first 2 meetings of the first step (2x2h) for 2 successive promotions (2004 and 2005). To record students and teacher activity during these sequences, we use 2 digital video-recorders and 3 wireless microphones. The microphones are hanged on the ceiling and the receptors are connected to the cameras. We use a wide-angle converter to have the whole classroom in the field of the VR1. The second camera is necessary to film what is going on in front of the blackboard. After recording, we put the 2 films on a computer to edit them. This is a simple editing which consists in incrusting the first film in the second one to facilitate our analyses.

To constitute our corpus, we made also some copies or photos of all the documents used and created by the teacher and the students in the classroom

After that, dialogues were transcribed and analyzed. For each class session (2h) we made first a detail description of the collective activity. Then, by using Leontiev' approach of activity we broke the description of the collective activity into different goal directed actions and each collective action into different individual operations. It is important to note that, in our case, actions and operations are principally composed of verbalisations and writings.

From the different collected data, we carried out 2 types of analyses:

- Longitudinal, which aims at comparing the successive actions and operations of the 2 groups (promotions 2004 and 2005) and to detail the impact of the teacher's interventions on the problem solving process ;
- Quantitative, starting from a categorization of each operation by means of a typology worked out in reference to the teaching objectives and the knowledge concerned in this first part of the sequence.

For this quantitative analysis, we defined 5 types of operations carried out by the students or the teacher according to the object towards the operation is directed.

Code	C1	C2	C3	C4	C5
Object	Goal(s) and intermediary goals to reach	Concepts, methods, and tools to use	concrete object names (ex : department of human resources ; manufacturing function)	Life context of knowledge (ex : teaching module 32 ; specific company)	Pedagogical organisation and means of the teaching sequence

Table 1: the different types of operations

We also sought to characterize, as far as possible, knowledge associated with these types of operations. To help us in these two analyses, we asked the teachers whose teaching modules are supposed to be remobilized during the sequence, to look at the recordings videos. They thus could deliver their opinion on the way how the students solve the problem and help us to identify knowledge mobilized by the pupils, and if the concepts or methods used come from their teaching modules.

6 Results

6.1 Longitudinal approach

In 2004, the teacher clearly asked the students to create an organisation by defining different functions. One student suggested to the others to do a brainstorming. All the students agreed with this proposal and gave several names of functions, departments and jobs without clear distinction between the terms used. Thereafter, one of them proposed to eliminate useless names and to regroup the others into few departments. At this moment, discussions became very strong, because some students did not agree with the meaning of different words and concepts. For instance, students discussed a lot about the meaning of logistics, and what a logistics department could be. During the brainstorming, the teacher left the classroom and let the students working by their own. He came back 10 minutes later but remained quiet until the students had considered they had defined all the departments of the company and wanted to go to the next step of the work. Then he stopped them and highlighted their confusions between *function*, *department* and *jobs*. He reminded them that he asked to define *functions* and not *departments*. He also explained that the risk in this step is to forget essential functions and suggested to the students to find a methodological approach learnt previously and making possible to check if

some important functions were missing. He supported a student who suggested simulating the "*customer order to delivered product process*". From this moment, he kept the hand on the orientation of the debate until he was convinced the objective was achieved.

In 2005, the teacher intervened in a very different way because he knew very well the industrial activity of one of the students in the group: this student, working on a Quality Management Project, daily mobilized the concepts of business process and function. On one hand, the teacher then solicited this student in a privileged way and supported him when this one proposed to start by defining the processes. On the other hand, he did not keep the proposal of another student, to start by defining the department. He left then the students free of the way to define their organisation. But much of them did not agree on the right way to achieve the goal. After having initially failed to define the complete order/delivery process, they discussed lengthily on the better way to solve the problem. Then, they tried successively several approaches. The very sharp debate, between the student at the origin of the process approach and some other students, turned unceasingly around the same point: was it necessary to start by defining the activities of this process or on the contrary to make a list of the department and then to define the tasks under the responsibility of these departments? The teacher refuted only few of the initiated attempts: sometimes he asked the students to specify or improve their proposals; sometimes he started again the debate between the partisans of the opposite directions: Process or department. He particularly supported the "process" student to defend his point of view. Then he went away from the classroom for a long time (24mn). After numerous discussions, the students agreed with the proposal of one of them which consists in defining a very general organisation chart. When he came back in the classroom, the teacher partially validated this organisation chart but he pointed out that the students had not used a method to check if all the functions were quite assured. The students used such a method during the following meeting, but they needed to be helped by the teacher to success.

6.2 Quantitative approach

		C1	C2	C3	C4	C5	Tot
T	n	67	68	84	48	101	368
	%	18,2	18,5	22,8	13	27	100
	Tp	200					
S	n	38	53	415	38	81	625
	%	6,08	8,48	66,4	6,08	13	100
	Tp	208					

Table 2 : Promotion 2004

		C1	C2	C3	C4	C5	Tot
Ens.	N	47	42	69	28	51	237
	%	19,8	17,7	29,1	11,8	22	100
	Tp	166					
Etu.	N	128	165	358	20	36	707
	%	18,1	23,3	50,6	2,83	5,1	100
	Tp	190					

Table 3 : Promotion 2005

Legend
n : number of operations; T : teacher ; S: students ; Tp : presence time in the classroom;
Cn : types of operations (see table 1)

The students'operations (in the sense of Leontiev) realised in 2004 dealt mainly with the names of organizational items (in fact, much more some departments names, than some function and process names) (more than 66%), compared to operations on goals (6%) and methods (8,5%). If we go in more details on these operations, action by action, this trend is still present: 7 actions (on 12) are composed of more than 73% of operation on concrete items. The teacher operations' are more balanced, as he always incited students to better consider goals and methods and he finally set the goals and the methods during the second part of the solving process.

In 2005 (see tab. 3), operations on concrete items were still the majority but with a lower percentage than in 2004 (only 50%). A deeper analyze shows that 8 actions (on 16) have operations on goals and methods with a high rate (20% to 50%), showing a very different configuration than in 2004. It's also important to notice that the teacher activity is different in the 2 cases : he was more active and present in 2004 (208 minutes in the classroom and 368 operations) than in 2005 (190 minutes in the classroom and 237 operations)

7 Interpretation of the results and discussion

The longitudinal analysis shows that the teacher can use different strategies to help and guide the students from a year to another. The strategy used in 2004 can be summarised as a 4 steps strategy: (1) to let the students free to use one method which is not very adapted to this type of problem; (2) to stop the students; (3) to show their mistakes and confusions only when they think they have finished; (4) to guide them strongly to the end of solving process. In 2005 the teacher's strategy aimed at stimulating much more the debate about the goals and the methods. Our quantitative analysis shows that these strategies have not the same effects on the students' activity. The second strategy (used in 2005) effectively promoted much more discussions about what can be the intermediate goals of the solving process and which methods can be used ; that was not the case in 2004 as showed by the table 2.

The teacher's strategies were different but the students' difficulties remained the same in 2004 and 2005. It is interesting to note that some knowledge transfers occurred easily. For example, a lot of students thought immediately about the brainstorming method (they have learned it previously in the quality teaching module), and most of them were able to suggest some department' names and to explain what these departments do. They did it from what they knew about the organisation of their company. But they had much more problems with the notions of functions and process. Moreover, none of them (except one student in 2005) reminded spontaneously the business process approach. All of them had difficulties to distinguish *functions* and *department*. Finally they were not able to really define what an organisation is. They very often remained at the

description of the enterprise in terms of departments, which do not reflect a common reality, because each company is organised differently, even if the departments' names could be similar. The consequence is that they hardly found an agreement about the definition of these departments because each student tried to prescribe his company's choices. In 2004 and 2005, they seemed to succeed in designing a company organisation after long discussions, but the discussions lead to superficial agreements. They were agreed only if they did not discuss too much about the definition and the content of each department. This approach is not enough to design an integrated management system.

Our work shows that the students were not able to solve such a complex problem alone. We can give some possible explanations of these difficulties, by using the activity theory approach. When they are in their company, all the students are apprentices affected in a department. They are located in an organisational chart, but never in a process. Their tutor is often in charge of the operations management, i.e. somebody positioned in a department and visible as a member of the organisational chart. The apprentices' tasks seldom exceed the activity system of their related service. The model process is almost invisible in the company, even more invisible for a young apprentice because it integrates activities led by actors resulting from various activity systems (departments). Moreover, at the university, the organisational concepts and the modelling methods are taught separately in different activity systems (i.e. disciplinary teaching modules). In our case, *functions* and *departments* have been studied in the stock management module and business process in the quality management module. Students had difficulties to understand that these concepts can be powerful beyond quality management problems, for example in an information system perspective.

We have shown that the teacher's role is crucial to help the students overcoming these difficulties and producing a model of the organization which is able to support an integrated information system. The teacher is like a *boundary actor*, between different activity systems, who help the students to overcome their natural tendency to use a *department approach*. He reminds them some more abstract knowledge like *functional approach* and *business process approach,* which have been taught previously and separately. These notions are more powerful both to understand what the common parts of specific companies' organisations are and to be able to modelise a complete new organisation from these different concrete experiences. In this sense, these conceptual tools are possible *boundary objects* between different activity systems.

8 Conclusion

In the perspective of training people in charge of implementing an ERP, we think it would be very interesting to develop similar pedagogical sequences,

mainly for 2 reasons: (1) to develop knowledge not only about specific domains of local activities (such as Information Systems domain), but also about the global organisation of the company, in terms of functions and processes ; (2) to learn how to define and use some *boundary objects* like the ones described in this paper which will be of powerful means to whom have to interoperate different activity systems.

Our work reveals the role of an experimented teacher to create and animate such a teaching sequence. He must know what is going on in the different activity systems of the vocational training (programs of the teaching modules; students' tasks in their companies). A young and non experimented teacher would have probably some difficulties to create such a teaching sequence. As we noticed in our work, video recording could be a very interesting way to develop collaborative work and experience between teachers, especially to reinforce the links between the different teaching modules. The teachers who saw our video recordings were very surprised when discovering the students' difficulties to solve the problem. They became aware that some aspects of their teaching modules had to be changed to develop the students' capacity to use concepts and methods outside their first context of learning.

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