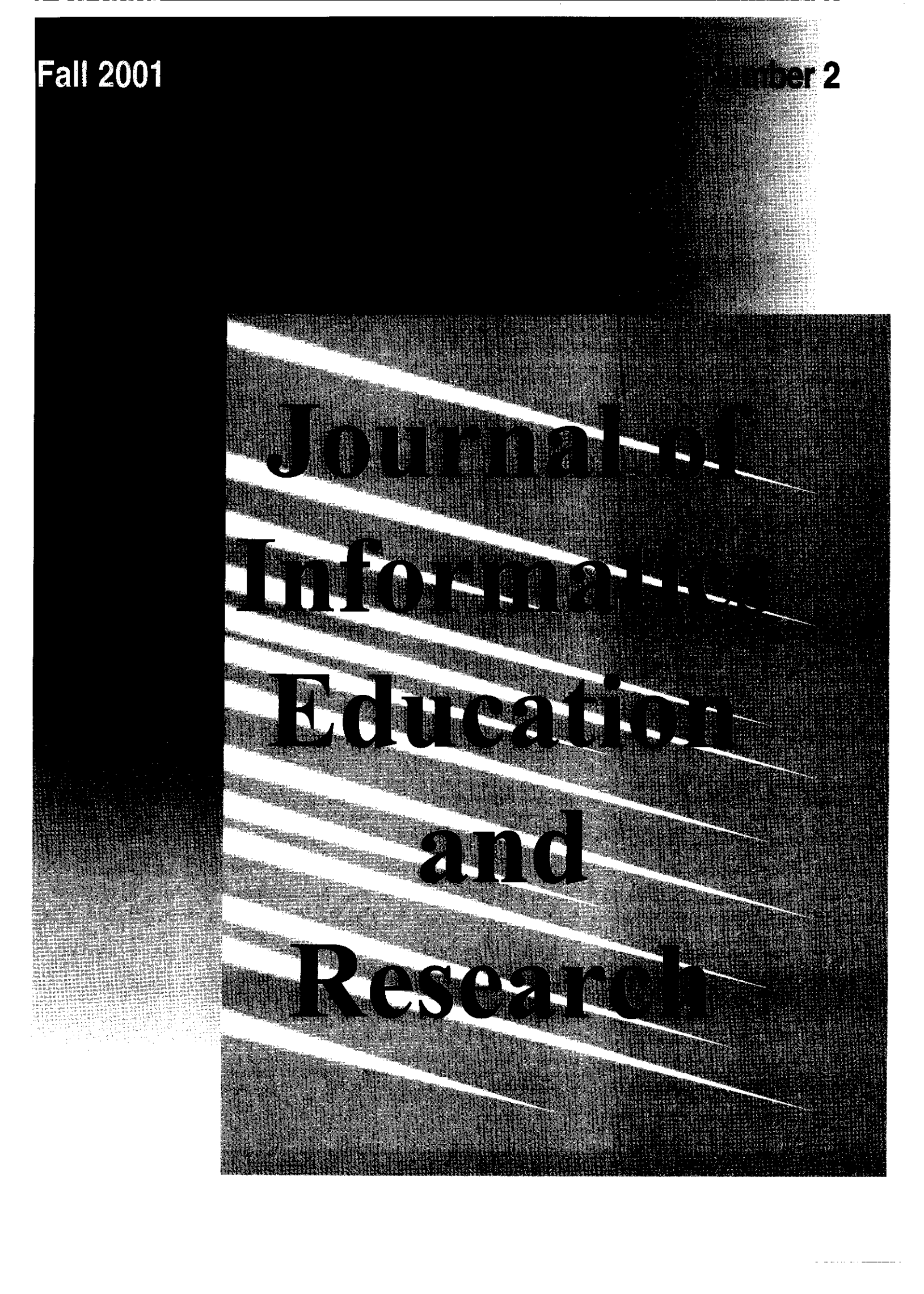


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TEACHING OBJECT-ORIENTED AND FUNCTIONAL PARADIGMS IN SOFTWARE ENGINEERING/DEVELOPMENT

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ABSTRACT

In the Information System (IS) development the so-called "functional" or "structured" paradigm has been traditionally used. Since the beginning of the last decade we have witnessed the publication of the "object-oriented" paradigm. Several authors have affirmed that object-oriented methodologies are "superior" and easier to learn than structured ones. We carried out research comparing the two paradigms as teaching methods for IS analysis and design. Our hypothesis was that object-orientation is a more effective method for teaching these system development concepts. But in our research this hypothesis has not been supported. A discussion of the reasons of this result and implications for future research are presented.

INTRODUCTION

In the development of Information Systems (IS) the so-called "functional or structured paradigm" has traditionally been used (Gane and Sarson, 1979; Yourdon, 1989; Yourdon and Constantine, 1989). In this classical approach, IS developers use a top-down breakdown depending on the required functionality. These methodologies are complemented by the use of conceptual models, such as the E/R model for the analysis of the data of the information system.

However, since the beginning of last decade we have witnessed the publication of new methodologies based on the "object-oriented paradigm" (Booch, 1994; Coad y Yourdon 1991 a; Coad y Yourdon 1991 b; Martin, 1993; Rumbaugh et al., 1991; Wirfs-Brock, Wilkerson y Wiener, 1990, etc.) in which the emphasis is on the objects making up the information systems. Object-oriented experts state that these methodologies provide better results when analysing and designing IS than the structured ones for two main reasons:

- They do not impose an artificial division of data and processes as occurs with the functional methodologies but they consider the objects as a whole.
- They diminish the great "gap" that exists between the space of the problem and the space of the solution in the development process of the information systems.

Currently a large number of companies and organisations are contemplating changing to object-oriented methodologies, which, in turn, recent years has begun to influence the curriculum of universities' computer studies and the competencies of the faculties. However, very few scientific studies exist comparing the efficiency of the structured methods with that of the object-oriented methodologies when teaching the IS development or the difficulties involved with this new focus in relation to previous methodologies.

In the next section looks at some investigations that compare the two approaches and finishes by detailing an investigation centred on the comparison of these two

approaches as teaching methods for the analysis and design of information systems.

RESEARCH COMPARING THE STRUCTURED APPROACH AND THE OBJECT-ORIENTED APPROACH

The following research compares the structured paradigm with the object-oriented paradigm in issues related to IS development.

- **Lee and Pennington (1994)**

This study analyses the different activities carried out by both experts and novices in IS design using object-oriented and structured methodologies. These authors find that object-oriented design can be easier and quicker than structured design as long as some problems encountered by novice designers when using object-orientation are taken into account.

- **Moynihan (1994)**

This paper summarises the results of the comparison of the two paradigms with regard to the validation of requirements for which two equivalent analyses, each made using a different paradigm, were given to a group of managers to make a critical evaluation of their content and format. These results contradict the opinion of the experts on object-orientation (like Meyer, 1996) as the managers considered the functional paradigm to be superior. However, it should be taken into account that this result could be due to the fact that these managers may be more accustomed to this type of paradigm and may therefore find it easier to understand.

- **Agrawal et al. (1996)**

This paper details an empirical analysis of the two methodologies applied to both process-oriented and object-oriented tasks. Their conceptual base is rooted in the theory of cognitive fit, which assumes that greater efficiency in the resolving of problems is achieved if both the problem to be solved and the tool to be applied are using the same kind of information. By means of a 2 x 2 factorial design they combine both object-oriented and structured (process-oriented) tasks and tools. The results indicate that the cognitive fit theory is valid, which leads the authors to suggest that it may not be convenient to apply the object-oriented approach in all the phases of development. These results leave this question unanswered particularly in the analysis phase.

- **Rossi and Brinkkemper (1996)**

In this study the authors apply complex metrics to compare the methods of development of traditional

systems with object-oriented methods. The authors draw attention to the importance of achieving a balance between the capacity of a method and the ease by which it can be learned; although the more powerful a method is the more effective it is for experienced users, and it also is the more difficult to learn.

- **Briand et al. (1997)**

This paper looks principally at whether object-oriented design documents are easier to understand and modify than structured design documents. There are various hypotheses of which the following two are the most significant: "a good object-oriented design is easier to understand and modify than a good structured design" and "a bad structured design is easier to understand and modify than a bad object-oriented design." Although the first hypothesis could not be confirmed, the second was.

- **Sheetz et al. (1997)**

Using cognitive mapping techniques, the authors study the perceptions of the students with regard to the difficulty they encounter in learning and using the object-orientated techniques. They highlight the great difficulty encountered when changing from the "philosophy" of structured paradigm to an object-orientated one, as well as the difficulty of working with libraries of classes and reuse (requisites of object-orientation). With regard to analysis and design the difficulty of working with CASE notations and tools orientated towards objects was clearly shown.

- **Shoval y Shiran (1997)**

These authors compare the extended E/R and object-oriented models with respect to quality design. The correctness of the design, the time needed to complete the task and the designer preference were taken as dependent variables, while the independent variable could take two forms: E/R or object-oriented. The authors conclude that the object-oriented model cannot be considered superior in any of the aspects studied. Since the E/R models obtains more correct schemes in less time and the designers prefer it, it is shown to be superior to the object-oriented model.

THE STRUCTURED AND THE OBJECT-ORIENTED APPROACHES AS METHODS FOR TEACHING AND DESIGNING INFORMATION SYSTEMS

This research is interested in comparing the two paradigms as teaching methods for IS analysis and design. It is believed that the objective of the approaches is to aid the students in their understanding of the basic

principles of any development, namely: modularity, information hiding, cohesion and coupling. Having analysed the two paradigms we agree with the experts on object-orientated methodologies that it is more natural than the functional breakdown when dealing with IS development. Therefore we propose the hypothesis that object-orientated paradigm (μ_2) is more efficient when teaching analysis and design than the structured paradigm (μ_1).

$H_0: \mu_1 < \mu_2$

As a result, when the conditions are the same (number of hours dedicated to the study, knowledge and previous experience, etc) the students should achieve better results when carrying out analysis and design using the object-orientated paradigm than when using the structured paradigm.

Method

Subjects. Participants were third year students studying the subject "Design and Use of Information Systems" as part of Technical Engineering in Computer Science in the Computer Science School of the University of Castilla-La Mancha in Ciudad Real (Spain). The students knew that data would be collected on certain tests (in which they participated as volunteers) but they did not know what the experimental hypothesis was that was being tested. One hundred and nineteen students participated in the first phase of the experiment, 21 of which were rejected during the experiment as they were retaking the course and therefore had already studied the two paradigms when studying the subject in previous years. Of the remaining 98 students 69 were men and 29 women. The average age of the students was between 21 and 22. One hundred and thirteen students participated in the second phase of the experiment, of which 24 were rejected as they were retaking the course. Of the remaining 79 students, 58 were men and 21 women.

Materials. In the first phase, all the participants received the same material, consisting of a formulation of a problem they had to resolve using structured techniques. In order that the proposed solution be independent of the teacher responsible for correcting the problem, this problem was adapted from Hoffer et al. (1996). Therefore, the criteria for judging the correctness of the students' design was based on the degree of similarity between the solution proposed by the students and that given by the authors. The second phase of the experiment was conducted in a similar way asking the participants to solve a problem presented by Yourdon and Argilla (1996), using object-oriented techniques.

Design and procedure. An experimental intra-subject design was used with only one independent variable (type of paradigm for the IS analysis and design), with two levels: level of structured paradigm and level of object-oriented paradigm.

The first phase of the experiment was carried out from September to December, during which time, the main concepts of the structured paradigm was explained to the students. In December, the students present in class were invited to participate in the experiment. The problem was given to each of them and without having given any kind of explanation was collected 45 minutes later. As can be seen in Appendix A, the answers were anonymous.

The second phase of the experiment was carried out from February to May and, in May, the object-oriented problem was provided, using the same technique from phase one. See Appendix B.

In both phases the score on a scale of 1-10 obtained in the corresponding exercise was taken as the dependent variable. This investigation can be classified, according to the criteria of Shulman (cited in Fernández 1995) as process-product, as it tries to estimate the effects of teaching practices (process) on students learning (product).

Results

The results obtained in the first phase are shown in Figure 1. The mean mark obtained during the first phase was 5.408.

**FIGURE 1
RESULT OBTAINED WITH
THE STRUCTURED PARADIGM**

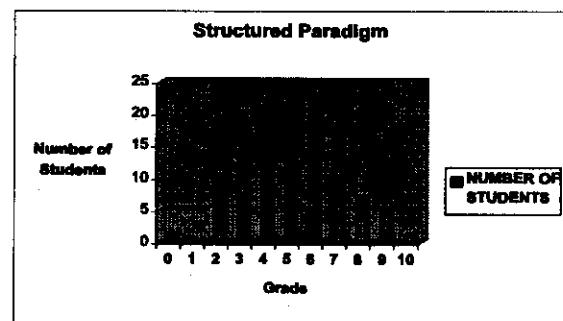
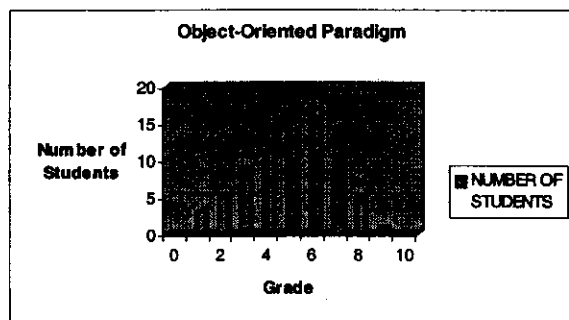


Figure 2 gives a summary of the results obtained during the second phase, whose mean mark was 5.101.

FIGURE 2
RESULTS OBTAINED WITH
THE OBJECT-ORIENTED PARADIGM



A one-tailed, statistical analysis based on the means, with the hypothesis $H_1: \mu_1 < \mu_2$ was not significant. Therefore, μ_1 represents the first average obtained using the structured paradigm and μ_2 represents the second average obtained using the object-oriented paradigm. If the variances of the populations of the two phases of the experiment, unknown, are supposedly equal, the result obtained, $t' = 1.046$ is not statistically significant at $t < -2.36$. Similarly, if, for the unknown unequal variances, $z' = 1.053$ there is no statistical significance at $z < -2.58$.

LIMITATIONS OF THE EXPERIMENT

This study has certain limitations which should be pointed out. Therefore, it is important to review the possible effects in the intra-subject designs, and whether they can be mitigated and, if so, to what extent.

Before the experiment:

- **Learning effect.** This has been controlled by using the different problems for each of the two paradigms. In this case, the issue is the level of difficulty of the examples. It is often difficult to find problems with the same level of complexity. Input was gathered from the instructors of the subject.
- **Tiredness effect.** This has been controlled as in both levels of the independent variable the students were in similar situations. (In the first phase before the Christmas holidays and in the second phase before the end of the course). It could be said that the students are more tired in May but it's also true that they have just had the Easter holidays.

During the experiment:

- **Practice effect.** This is the effect that may have had most influence in the experiment as the students first worked with the functional paradigm and then with the object-oriented one and as a result had accumulated practice when working with the latter. The problem could be resolved in two ways:

1. Divide the students into two groups so that each group starts with a different paradigm.
2. In the next course start with the object-oriented paradigm.

In any case, this effect should have benefitted the object-oriented paradigm, and therefore it may not have influenced the result of the experiment.

- **Persistence effect.** This effect may have influenced the result of the experiment in the same way as in the previous case and could be solved by using either of the proposed solutions.

DISCUSSION

Although some of the limitations have the potential to impact the results of the study, it appears that contrary to the predominant opinion held in Software Engineering, the object-oriented paradigm is more efficient when teaching the principles of system analysis and design.

Accordingly, the data obtained would confirm studies like that of Shoral and Shiran (1997) previously mentioned, which also did not demonstrate the superiority of the object-oriented paradigm. Applying the theory of cognitive fit, as done in Agrawal et al (1996) it may be affirmed that in the analysis phase, at least for the type of problem used in the tests, the structured paradigm adapts as well as the object-oriented one. It should be emphasised that the examples selected have all been taken from the area of Information Management, and that different results may be obtained if other types of problems, such as those related to real time, or process control (areas in which until recently object-orientation has had more diffusion) were used.

With regard to the teaching of Information Management, serious consideration should be given to the difficulties students may encounter when implementing object-oriented development. Difficulties may arise in the first years of the degree, especially due to the choice of the first programming language. This language has always been Pascal without any attention to object-orientation.

Currently some universities are beginning to teach object-oriented languages as first learnt languages, which should undoubtedly lead to a better understanding of the concepts of this paradigm, which would in turn lead to a better understanding of object-oriented analysis and design. In the Computer Science School of Ciudad Real with the implementation of the new curriculum in this academic year this change is also taking place and Java will be adopted as the first programming language. In two years it will be possible to evaluate the results of this change and whether it contributes to raising the level of our students' expertise in the area of object technology.

CONCLUSIONS AND FUTURE STUDIES

It is fundamental in computer science degrees to investigate the impact of teaching the principal concepts of software engineering, which constitutes the basic nucleus of these degrees. This research work is even more important when there are significant fundamental changes, such as the switch in paradigm from structured analysis and design to object-oriented analysis and design.

However, this experience leaves a great number of questions unanswered. In the future there should be

more investigation into the object-oriented paradigm. Some methods to further this research are: applying the experiment to another type of problem, reversing the order of exposure (structured-objects for objects-structured), comparing the performance of the students who have learned a structured language first with those who have learned an object-oriented language first. It may be possible that the object-oriented paradigm is appropriate for large-scale systems, not smaller-scale systems used in a university setting. This research raises many issues for future research.

This paper reviewed some of the investigations that compare the two paradigms. Although the hypothesis on which the investigation was based was not supported, the result of the experiment has been very positive as it may cause universities to investigate certain affirmations concerning the object-oriented paradigm not been backed up by serious study.

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**APPENDIX A
EXERCISE OF STRUCTURED ANALYSIS AND DESIGN**

AGE: SEX:	GROUP: REPEATING:
<p>Construct the dataflow diagrams necessities to represent the following problem.</p> <p><i>The objective is to design the system for recruiting personnel in the company Alarcos, S.A., a computer consultancy company that keeps a register of all its employees. The new employees are taken on the basis of the information given in their curriculum and after a series of interviews.</i></p> <p><i>Anybody can send their curriculum or an update to the company at any moment.</i></p> <p><i>The head of the computer department informs the personnel department when it is necessary to create new posts, detailing the preparation and knowledge necessary to carry them out.</i></p> <p><i>The personnel department compares the characteristics of the possible employees (to be found in the curriculum that have been sent) with those of the post and organizes the interviews between the head of the computer department and the three best candidates.</i></p> <p><i>Having received the evaluations of the head of the computer department, the human resources notifies the candidates interviewed and the head of the computer department of the decision taken. The new employees are asked to fill in a form with additional data to that in the curriculum and it is put together with that of the rest of the employees in the company.</i></p>	

APPENDIX B
EXERCISE OF OBJECT-ORIENTED ANALYSIS AND DESIGN

AGE: SEX:	GROUP: REPEATING:
<p>Construct the class model for the following problem:</p> <p><i>The objective is to design the subscription system for the magazine ALARCOS, S.A., which is published monthly. Each issue consists of 5 to 10 written articles by various authors. These authors do not receive any payment, but only a free subscription as a sign of gratitude. The magazine does not want to publish more than two articles per year by each author. The magazine has an editing committee whose members can also write articles.</i></p> <p><i>The subscribers to the magazine may be individuals or companies, who can order several copies of the same magazine. The tariffs vary depending on the country of the subscriber and the discounts to which he is entitled according to different criteria. There is a list of personalities and institutions to whom the magazine is sent free of charge.</i></p> <p><i>Furthermore there is a list of "potential" clients who have requested information about the magazine or to whom a free issue has been sent, but who have not become subscribers.</i></p> <p><i>In order to renew subscriptions letters are sent some months before the subscription expires, which can be paid by cheque, credit card or bank transfer.</i></p>	

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