Empirical and Theoretical Evaluation of USE and OCLE Tools

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Abstract: Validating the conceptual model (CM) is a key activity in ensuring software quality and saving costs, especially when adopting any type of Model-driven Software Engineering methodology, in which standard modelling languages such as UML and tools support for validation become essential. This paper analyses and evaluates the main characteristics of the tools to support test-based validation in CMs. For this, two research approaches were used: (1) an empirical evaluation to compare the effectiveness and fault detection efficiency in a CM and analyses the level of ease of use of two tools used to validate requirements in UML conceptual models, and (2) a complementary theoretical analysis. The study focuses on the class diagram, the most common type of UML diagram, and two tools widely used by the modelling community for test-based validation: USE and OCLE. Theoretical and empirical comparisons were carried out with the aim of selecting an appropriate tool to validate UML-based CMs with OCLE achieving a better score.

1 INTRODUCTION

Testing is an essential part of the software development life cycle (Ayabaca & Moscoso Bernal, 2017) as it allows the software engineer to find defects, which can have a great impact on the project's budget. It is thus very important to detect and eliminate them in the early stages of the development process, for example, at the conceptual model level, especially when Model-Driven Software Engineering (MDSE) is used.

A conceptual model is an application that designers want users to understand. There are many ways to describe a conceptual model (Ayabaca & Moscoso Bernal, 2017), such as: entity-relationship diagrams, class diagrams based on the Unified Modelling language (UML), process diagrams based on Business Process Model and Notation -BPMN (OMG, 2018), etc. On the language side, UML is the *de facto* standard for modelling software systems. UML (OMG, 2017) provides several diagrams to model the structure of a software system, its architecture and its behaviour.

Several commercial and open source tools to support UML modelling are available, e.g. MagicDraw, Papyrus, USE, OCLE among many others[1]. Although each one has different characteristics, all of them offer a graphic editor to assist in defining the UML models and facilities to verify the finished model. However, we believe that a theoretical and empirical comparison is needed to help select a tool that can validate a UML-based CM.

The study has two contributions to the current literature: (1) a theoretical evaluation of two tools that can be used to execute tests at the level of class diagrams specified in UML and (2) an empirical and comparative evaluation using TAM model (Technology Acceptance Model) (Sauro & Lewis, 2012). We review the state of the art of UML class diagram validation tools. Two of the most appropriate tools are selected by analysing main characteristics, advantages and disadvantages. An empirical and comparative evaluation of the selected tools is conducted to compare task oriented metrics such as effectiveness, efficiency and ease of use of the tools (Wetzlinger, Auinger, & Dörflinger, 2014).

This paper is organized as follows. Section 2 describes the background and the related work. Section 3 describes the theoretical comparison of the selected tools. Section 4 summarizes the experimental plan of the empirical evaluation, as well as its main

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results. Section 5 contains the final discussion of the findings. Section 6 summarizes the threats to validity and the conclusions and future work are summarized in Section 7.

2 BACKGROUND AND RELATED WORK

Software modelling is carried out by humans and so is prone to defects being introduced in CMs, such as: (1) missing, (2) inconsistent, (3) incorrect, (4) redundant, and (5) ambiguous (Granda, 2015). The number of defects should be minimised to reduce the impact on software quality through different verification and validation techniques, including testing. Validation and Verification consists of manipulating a CM under controlled conditions to: (1) verify that it behaves as specified; (2) detect defects and (3) validate user requirements (Sommerville, 2011). As requirements validation is difficult to judge solely by inspecting models, an executable model is needed to evaluate the CM and detect any misconceptions expressed in it.

Although, commercial programs are available as they require a license they are outside the scope of this work. We also found several tools to manage and verify CM based on UML class diagrams (e.g., Dia[2], Lucidchart[3], Magic Draw[4], and Visio[5], among others), although they do not support the test-based validation process, so were not considered in this work

According to (Myers, 2004), testing a program (in our work, a CM) is trying to make it fail by injecting defects into the software artefact. According to (Tort, Olivé, & Sancho, 2011), the tests that can be performed at the conceptual model level are related to the verification of: (1) the consistency of a state, (2) the inconsistency of a state, (3) the occurrence of a domain event, (4) the non-occurrence of a domain event, and (5) verifying the content of a state. For example, to instantiate an object at the model level and test whether it meets the constraints (i.e. pre-conditions, post-conditions, and invariants) that are expected as the objects change state, during the execution of a test case. In this case, as there are other failures to be analysed, a tool that allows the execution of test cases to validate the conceptual model should be used. This validation is very useful during the software analysis and design phases, when it is required to determine at an early stage whether the CM meets the specified user requirements (Ayabaca & Moscoso Bernal, 2017). In our study we used Object Constraint Language (OCL) (OMG, 2013) to include the restrictions in a CM.

(Yu, France, Ray, & Lano, 2007) propose an approach to automatically generate a sequence of behavioural snapshots. The constraints on these snapshot sequences are expressed by the OCL. In this way modelling behaviour allows designers or software engineers to use tools like USE[6] and OCLE[7] to analyse behaviour. This study helped us to identify software that validates CM at the level of UML class diagrams. Additionally, (Planas & Cabot, 2020), analysed how modellers build UML models and how good the modelling tools are to support the task of obtaining a complete and correct CM based on a definition of the requirements based on two programs, one of which is commercial (i.e. MagicDraw). (Bobkowska & Reszke, 2005) are considering a set of six programs and focused on finding the fastest modelling software and the features that make it more efficient.

The present study adds a new perspective to previous publications by carrying out an empirical and comparative evaluation of tools that can be used to detect defects through the execution of test scripts on CMs using UML. For this, it focuses on the class diagram, the most widely used UML diagram (Dobing & Parsons, 2006), and other open source modelling tools that automate the execution of test scripts. To the best of our knowledge, the present study is the first to analyse the effectiveness, efficiency and ease of use of UML modelling software from the point of view of test-based validations of class diagrams.

3 THEORETICAL ANALYSIS

In this work, we selected USE (UML-based Specification Environment) and OCLE (Object Constraint Language Environment) because they contain a language to write and execute test cases, are open access, and still have support. Table 1 contains a summary of the USE and OCLE characteristics. These include: (a) *general characteristics* of their operations; (b) *validation options,* associated with their different methods of performing validation processes; and (c) *edition options*, or the different ways of editing a CM and its visualization. These three groups of characteristics were defined by the authors as a preliminary step to their evaluation.

[2] www.dia-installer.de/
[3] www.lucidchart.com/pages/
[4] www.nomagic.com/products/magicdraw
[5] www.products.office.com/en-in/visio/flowchart-software
[6] http://www.db.informatik.uni-bremen.de/projects/ USE-2.3.1/#overview
[7] http://lci.cs.ubbcluj.ro/ocle/overview.htm

Table 1: Summary of USE and OCLE characteristics.

Criteria of selection	**Tools**	
General characteristics	*USE*	*OCLE*
Open access software	●	●
Supports multiplatform	●	●
Technical support	●	●
Validation options		
Validation based only on class diagram	●	●
Constraints validation language	●	●
Language for test cases	●	●
Command line validation	●	●
Running batch scripts	●	●
Edition options		
Graphical CM editing		●
Textual CM editing	●	●
Text editor for constraints		●
Editing values of object model instances	●	●
CM Graphic visualization	●	●

For the theoretical comparison from the tester perspective, relevant comparison criteria were selected by convenience sampling (Etikan, Musa, & Alkassim, 2016), and grouped as: (i) application domain, (ii) types of verifications, (iii) types of validations admitted, (iv) quality in terms of defect types detected and validation objectives; and, (v) CM validation environment (see Table 2). Both tools support UML 2.0, which provides a more extensible modelling language and allows CM validation and execution. In USE, the CM is defined in USE code and the restrictions in OCL and the two languages are defined in the same file with extension ".use".

In OCLE, the model is defined in a ".xml" file. The restrictions are in a file with the extension ".ocl". Finally, there is a file with the extension ".oepr" which contains the CM and the OCLs in a single project. The relationships between the elements of a CM that these tools support are based on UML relationships (association, generalization, etc.). Modelling at the metamodel level is only supported by OCLE, and this modelling refers to the creation of several CMs within of the same project. Both programs can verify the data type entry both at the level of attributes, parameters and returned values of methods, as well as pre-conditions, post-conditions and invariants. The difference is that USE restrictions are entered in the project file using a separate text editor, while in OCLE they can be entered or modified by its graphic interface.

In the validation process, both USE and OCLE perform validation techniques through CM tests and CM simulation by using the object diagram. The CM analysis in USE is automatic, since the CM is validated when loading the project, while in OCLE the CM is analysed after loading. All the classes, relationships and restrictions are present, but the class diagram is not displayed, and the diagram must be created by dragging all the elements to a panel where you can finally see how the diagram is designed.

Table 2: A technical comparison between selected tools.

Analysed Characteristic		**USE**	**OCLE**
Domain	Modelling	UML 2.0	
	Language used by the tool	USE notation	OCLE notation
	CM Format	(.use)	(.ocl, oepr, .bcr)
	Creation of elements	USE notation	Manipulating the graphical interface
	Relationships it supports	Association, Generalization, Composition, Dependency	
	Supported diagrams	Diagrams of classes, objects, sequence	Diagram of classes, use cases, objects.
Verification	Type of data	Yes	
	Syntax	Yes	
	Constraints (Invariants, pre-conditions, post-conditions)	Using text with OCL notation	Graphical interface with OCL notation
Validation	Supported Validation Techniques	• CM testing • CM simulation	
	Automation level	Automatic	Semiautomatic
	Supported Test Cases Types	• Inconsistency of states. • Domain of a specific state. • The non-occurrence of an event. • The undue occurrence of an event.	
Quality	Types of detected defects	• Missing element • Incorrect item • Unnecessary item • Syntax when entering data	
	Purpose of Validation	• Check consistency • Correctness • Completeness	
Execution	Environment	USE	OCLE
	Simulation feedback	Yes	
	Types of messages in feedback	Messages in the console and graphical interface.	Messages in the graphical interface.
	Batch test scripts	Yes	
	Location of faults in the CM	Yes	
	Constraint Execution Feedback	Yes	No

We used the types proposed by Tort (Tort et al., 2011) to analyse the types of test cases supported by both tools, which were the same in each case. The quality of CM validation types was analysed. According to (Aladib, 2014), USE and OCLE detect the same defects types: missing elements, bad elements, unnecessary elements, and syntax when entering data. Both programs aim to verify CM consistency, correctness and completeness.

When executing the CM, USE presents a window with the validation results executed, whereas OCLE displays a drop-down menu of all the CM elements showing all the validations in the form of messages, while the elements are being selected from the menu. For CM simulation feedback, both USE and OCLE rely on simulating the CM by means of an object diagram. They also allow batch test execution, i.e. a set of validations can be executed in a single process. Both programs allow you to locate any defects within the CM, OCLE indicates defects hierarchically (project name - object - attribute name - incorrect value), while USE locates defects directly by displaying the CM element with a description. Both allow correction of the elements until obtaining a validated CM.

Based on the analysis carried out, it can be said that USE and OCLE have similar characteristics in the selected comparison criteria, with few differences in terms of functionality and characteristics: (a) each has its own notation/language, (b) the structure of a USE project contains a single file, while OCLE is made up of several types of files, (c) the diagrams supported in both tools, (d) how to insert the constraints in an CM, (e) the level of automation that supports validation, (f) the execution environment, (g) types of messages in the feedback and, (h) feedback in the execution of the constraints. The remaining analysed characteristics of domain, verification, validation, quality and execution are similar.

4 EMPIRICAL EVALUATION

This section describes the experimental plan, the environment in which the experiment was carried out, the procedure used and the data collection and analysis.

4.1 Experimental Planning

The experiment was designed according to (Wohlin et al., 2012) and reported according to (Juristo & Moreno, 2001). The goal definition is aligned with the GQM (Goal/Question/Metric) paradigm (van Solingen & Berghout, 1999).

4.1.1 Goal

To analyse USE and OCLE, **for the purpose of** comparing them in a theoretically and empirically way, **with respect to** their effectiveness and efficiency in detecting faults in CMs and ease of use when using these tools, **from the viewpoint of** researcher, **in the context of** Computer Science students interested in validating requirements.

4.1.2 Research Questions

- RQ_1: Is there a significant difference between the degree of USE and OCLE's effectiveness in detecting defects CMs?
- RQ_2: Which of the two tools has a higher degree of efficiency in detecting the greatest number of defects in a CMs?
- RQ_3: Is the perception of ease of use impacted when the subjects are validating the CMs using the selected tools?

4.1.3 Hypothesis

Three hypotheses were defined (see Table 3). The null hypothesis (represented by the subscript 0) referred to the absence of an impact of the independent variables on the dependent variables. The alternative hypothesis involved the existence of an impact and was the expected result.

Table 3: Specification of hypothesis.

Null Hypothesis	Declaration: The type of tool does not influence …
H_{10}	… the effectiveness of the subjects in detecting faults in the conceptual models.
H_{20}	… the efficiency of the subjects in detecting faults in the conceptual models.
H_{30}	… the subject's perception of ease of use.

4.1.4 Variables and Metrics

a) ***Independent Variables***: The validation tool was considered as an independent variable (Juristo & Moreno, 2001). This variable can have two values (also known as treatments (Juristo & Moreno, 2001)): (i) users apply the USE tool, and (ii) users apply the OCLE tool.

b) ***Dependent Variables and Metrics***: The four dependent variables (Juristo & Moreno, 2001) are:

- **Effectiveness in Detecting Defects** (Eldh, Hansson, Punnekkat, Pettersson, & Sundmark, 2006**)**. To investigate RQ_1 it was necessary to measure the tools' effectiveness in finding defects. The result was a percentage that allowed a comparative assessment, i.e., the lowest two percentiles, were ineffective, while capacity improved as it rose to 100%.

$$effectiveness = \frac{finding\ defects}{injecting\ defects} * 100 \quad (1)$$

- **Efficiency in Detecting Defects** (Eldh et al., 2006**)**. This variable allowed RQ_2 to be investigated and its metric was calculated according to the following formula:

$$efficiency = \frac{finding\ defects / time\ invested}{expected\ defects / expected\ time} \quad (2)$$

The result was a value that allowed the tools to be evaluated comparatively, considering that the higher values presented greater efficiency and the lower values a deficiency (Eldh et al., 2006).

- **Ease of Use**. The degree to which a participant considers a validation tool is effortless. This variable responded to RQ3. To calculate this metric, the TAM model was considered. We used a 7-point Likert scale to measure ease of use of the tools, which is the arithmetic mean of this scale.

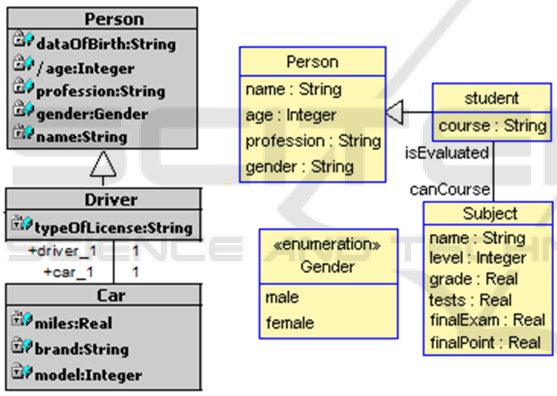
4.2 Experimental Context

4.2.1 Subjects

The experiment was carried on 18 subjects (2 women and 16 men) between 18 and 22 years old, all Computer Science's students of the University of Cuenca, with proven experience in conducting tests at the code level, as well as in the use of modelling methods and techniques, e.g. UML diagrams.

4.2.2 Conceptual Models

Four different conceptual models were used in our study, two (CM A and CM B) for the training session, and the other two (CM C and CM D) for the experimental session with OCLE (Figure 1(a)) and USE (Figure 1 (b)). The CMs contain a variety of features in a UML class diagram, including classes, relationships, and different types of constraints.



a) Class diagram for CM C using OCLE tool

b) Class diagram for CM D using USE tool

Figure 1: Class diagrams of a) CM C and b) CM D.

4.2.3 Failures Injected into CMs

In this paper, we decide to consider five defects which were injected into each CM used in the experimental phase, as described in Table 4. These defects were randomly selected from a list of defects previously obtained from each model. According to a pilot study which was carried out to validate the experimental material, the expected average time to detect the five defects is 3 minutes for each one.

4.3 Experimental Procedure

This section describes in detail the procedures used to carry out the experiment.

Table 4: Defects in CM C and CM D.

Defect	CM C	CM D
Missing element	A restriction is missing to validate the age.	A constraint is missing to validate that the course has a value between 1 and 10.
Missing element	Gender enumeration (male, female) is missing.	A restriction is missing to validate that the value of the "finalPoint" of the student corresponds to the sum of "finalExam", average of "tests" and average of "grade".
Missing element	A restriction is missing on the name to validate the entry of only alphanumeric characters.	A restriction is missing that allows validating that the derived attribute "age" of the person class is greater than zero and that it is generated from the date of birth.
Missing element	A restriction that validates the entry of the miles with correct values is missing (they must not be negative values).	
Incorrect element	The cardinality of the Driver-Car relationship is not correct, since a driver can be assigned a maximum of two cars.	The restriction that validates the total score is incorrect, it must validate that the value of "finalExam" is less than or equal to 100.
Incorrect element		The "gender" attribute must not be of type String but of the enumeration type "Gender".

Intensive training sessions were designed to homogenize the knowledge and experience in the use of the tools. Figure 2 summarizes the experimental process, which was divided into the following sessions.

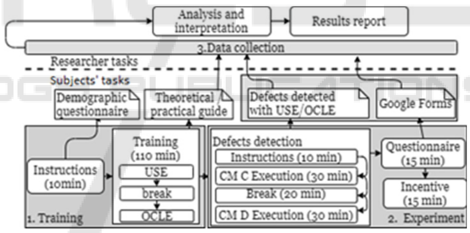


Figure 2: General scheme of the experiment.

4.3.1 Training Session

A general description of the tasks to be carried out was made, after which the subjects filled out the demographic questionnaire (ten minutes). Training in the use of USE by CM A was then given. CM B was used to train OCLE. During the 2-hour training session the subjects solved some exercises and received feedback on their performance.

4.3.2 Experimental Session

This session had an estimated duration of two hours and was distributed as follows: (i) The subjects were divided into two groups, the instructions on the activities to be carried out were given (10 min) in a document that included the description of each proposed CM, and it allowed the information on the defects found by the subjects to be recorded (description of the defect, defect found, defect corrected, initial and final times). During the defect detection they recorded the time it took to find each defect using a digital clock. The subjects did not know the number of defects injected into the CMs and themselves decided when to end the defect analysis; (ii) the first part of the experiment was carried out (30 min), the first group of subjects used USE, the second group used OCLE and both used the CM C model (see Figure 1 (a)); (iii) a 20 minutes break; (iv) the second part of the experiment was carried out (30 min) where the first group used OCLE and the second group used USE with the CM D (see Figure 1 (b)); (v) the subjects answered the questionnaire on ease of use for USE and OCLE (15 min); and, (vi) finally an incentive was given to the subjects for their participation in the experiment (15 min).

Additional information about the questionnaire and the score of each participant, as well as the injected and detected defects can be accessed on the site http://t.ly/1mpu.

4.4 Analysis and Interpretation of Result

This section summarizes the results of the evaluation.

Since RQ1 was to evaluate the tools' effectiveness in detecting defects, the number of defects found by each in the different CMs was compared. Table 5 shows those defects detected (Column 2) by each subject, and the Effectiveness value (Column 3). The time spent and expected time data (columns 4 and 5) were used to calculate the detection efficiency (Column 6). The user satisfaction value is shown in Column 7. Shapiro-Wilk tests, appropriate for <50 samples, were performed to assess the normality of the samples.

4.4.1 Defect Detection Effectiveness

These variables did not follow a normal distribution (<0.05) since the Sig. Values for the Shapiro-Wilk tests were 0 for USE and 0.001 for OCLE. The data obtained from both programs was considered in two independent groups.

The Mann-Whitney U test was used to test our first null hypothesis (H_{10}). Figure 3 (a) shows the box plot containing data on both programs' effectiveness in detecting defects and Table 6 shows the results of the Mann-Whitney U test.

It can be seen that the subjects' effectiveness differs according to the program used. In this case, OCLE scored better than USE. We therefore did not accept the null hypothesis H_{10}. In other words, the effectiveness is different for each tool, U=69.5, 2-tailed p-value =0.001<0.05.

Table 5: Data collected by tool.

Tool	Detected Defects	Effectiveness (%)	Time spent (min)	Scheduled time (min)	Efficiency (%)	Ease of Use (mean)
USE	2	40	3	6	0.8	6.17
	2	40	5	6	0.5	2.00
	2	40	15	6	0.2	2.00
	4	80	5	12	1.9	1.83
	2	40	6	6	0.4	2.50
	3	60	19	9	0.3	3.50
	2	40	8	6	0.3	3.33
	2	40	17	6	0.1	4.83
	3	60	10	9	0.5	1.67
	3	60	16	9	0.3	1.00
	2	40	16	6	0.2	1.17
	2	40	10	6	0.2	2.67
	2	40	8	6	0.3	2.33
	3	60	9	9	0.6	2.17
	2	40	4	6	0.6	4.50
	2	40	5	6	0.5	4.83
	2	40	6	6	0.4	3.33
	2	40	8	6	0.3	4.83
OCLE	3	60	10	9	0.5	4.33
	2	40	5	6	0.5	4.67
	3	60	9	9	0.6	5.00
	3	60	6	9	0.9	2.83
	3	60	7	9	0.8	4.50
	4	80	9	12	1.1	5.50
	4	80	17	12	0.6	1.67
	3	60	8	9	0.7	5.17
	3	60	10	9	0.5	4.67
	4	80	14	12	0.7	5.17
	3	60	9	9	0.6	5.17
	2	40	5	6	0.5	5.00
	3	60	6	9	0.9	4.50
	2	40	3	6	0.8	2.83
	3	60	12	9	0.5	5.17
	3	60	9	9	0.6	4.33
	4	80	22	12	0.4	4.67
	3	60	16	9	0.3	4.67

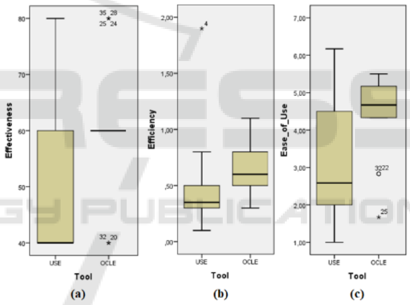


Figure 3: Box Plot for dependent variables per Tool.

Table 6: Values of the Mann-Whitney U Test for dependent variables per Tool.

Test Statistics[a]	Effectiveness	Efficiency	Ease of Use
Mann-Whitney U	69,500	69,000	73,500
Wilcoxon W	240,500	240,000	244,500
Z	-3,197	-2,975	-2,806
Asymp. Sig. (2-tailed)	,001	,003	,005
Exact Sig. [2*(1-tailed Sig.)]	,003[b]	,003[b]	,004[b]
a. Grouping Variable: Tool b. Not corrected for ties			

4.4.2 Defect Detection Efficiency

As in the previous analysis, all Sig. Values for the Shapiro-Wilk tests were 0.0 for USE and 0.401 for OCLE, which means that these variables did not have a normal distribution (that is, <0.05). Considering both types of data as independent groups, the non-parametric Mann-Whitney U test was selected to evaluate the second null hypothesis (H_{20}). Figure 3 (b) shows the box plot containing data on the programs' efficiency in detecting defects and Table 6 gives the results of the Mann-Whitney U test. Given that the detection efficiency is also affected by the type of tool, OCLE performed better than USE (U = 69.000, 2-tailed p-value = 0.003< 0.05), making hypothesis H_{20} invalid.

4.4.3 Ease of Use

Our objective in RQ_3 was to detect any difference in the ease of use score between USE and OCLE, for which the overall score obtained from the 18 subjects was compared (see Table 5, Column 7). Figure 3 (c) shows the box plot of the data collected for the ease of use score for each tool. As the results show, the score values gave a better result for OCLE than USE.

As in the previous analysis (RQ_1 and RQ_2), the Shapiro-Wilk test was performed on the collected values. The Sig. Value was 0.218 for USE and 0.001 for OCLE, which means that this variable does not have a normal distribution (<0.05). Considering both groups of independent subjects, we selected the Mann-Whitney U test (non-parametric test) to evaluate the hypothesis H_{30}.

From these data (see Table 6), it can be concluded that the OCLE ease of use score was statistically more significant than that of the USE tool, which means that we did not accept the null hypothesis H_{30} and concluded that the ease of use perceived by the subjects was different for each tool; (U = 73.500, 2-tailed p-value = 0.005 <0.05).

5 FINAL DISCUSSION

In this section, the findings of the empirical experiment are discussed and interpreted according to the research questions posed in Section 5.

From the empirical experiment, it was observed that the effectiveness and efficiency show a significant difference between both programs. This difference is related to the mechanism and obstacles that the subjects encountered when using both tools (a little more in USE). The difference is due to the programs' defects reporting mechanism. USE detects defects from the messages in its graphical and textual interface, which takes a little more time, while OCLE does so only in its graphic interface.

Some subjects highlighted that "the languages used by the tools are intuitive and easy to use" and some subjects indicated that "the information provided by the tools was useful to distinguish the type of defect and locate it in the CM". Through the analysis of the TAM model, it was determined that OCLE presents better results in terms of ease of use when used to validate MCs. This could have been due to the different facilities or the steps required for the process.

Therefore, from these results we can conclude that OCLE is better than USE in defects detection in terms of efficiency, efficacy and ease of use.

Regarding the practical implications and applicability for model-driven practitioners, we consider it important to emphasize the use of best practices in conceptual modelling, such as those detailed in (Kuzniarz & Staron, 2005). It should also be remembered that some elements in a class diagram must be created in a specific order even if only for pragmatic reasons.

6 THREATS TO VALIDITY

Regarding internal validity, our threats are mainly associated with the subjects and measurements. First, the subjects in our experiment might have had different prior knowledge of the tools before the experiment (in the demographic questionnaire we explicitly asked for this information and all claimed they were unfamiliar with the tools), so we tried to minimize this threat by training to homogenize their knowledge and experience. Second, in order to guarantee identical conditions for the experiment, all the computers had the same operational conditions, material, and MCs with equal complexity.

Regarding external validity, our threats are related to the selection of modelling tools (OCLE and USE), since they can have particular characteristics that influence the time required for the detection of defects. This threat was mitigated by selecting tools with similar features and functionality. However, the results of this experiment should not be generalized to the modelling tools population were considered. In future work we plan to replicate this study incorporating commercial tools. Despite the fact that the experiment was performed in an academic context, the results could be representative with regard to novice testers with no experience in CM validations. With respect to the use of students as experimental subjects, several authors suggest that the results can be generalised to industrial practitioners (Runeson, 2003).

Conclusion validity threats were mitigated by the design of the experiment. We took a group of 18 students as a sample from the Systems Engineering course. Furthermore, adequate tests were performed to statistically reject the null hypothesis. The metrics used allowed us to objectively evaluate the subjects' effectiveness, efficiency and ease of use. As the validity of the conclusion could be affected by the number of observations, additional replicates with a larger data set will be required to confirm or contradict the results obtained. The ease of use questionnaire was designed using standard questions and scales that have been shown to be highly reliable.

7 CONCLUSIONS AND FUTURE WORK

Two research approaches were used to compare CM validation tools based on UML class diagrams. First, a theoretical analysis of the characteristics of these tools was carried out using several criteria, i.e., they had to be free license tools that support the creation and execution of CM validation test cases. The second research approach was to conduct an empirical evaluation to compare the effectiveness, efficiency and ease of use perceived by USE and OCLE users.

The experimental evaluation reported notable differences in the programs' effectiveness, efficiency and ease of use with OCLE achieving a better score.

As a future work, we plan to extend this study considering other UML modelling tools (including commercial tools) and also integrating other UML diagrams to represent a conceptual model (e.g., activity, sequence), to see whether the results of this study can be generalized. Finally, we intend to implement a new validation tool that combines the most outstanding functions of the different tools analysed and solve any deficiencies found in them.

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