Soft Systems Methodology in an Educational Context—Enhancing Students Perception and Understanding

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***Abstract*—This study was performed within a graduate course in the Organizational Development and Consulting graduate program. The course draws a comparison between the systems analysis processes used in computing systems (hard systems) and the organizational analysis methodologies applied in soft systems, such as Checklands' Soft Systems Methodology (SSM). Since most students' previous academic experience is in social sciences, abstract concepts related to computing systems were difficult to comprehend. The SSM that is mainly used for unstructured and poorly defined problems was exercised for identifying the students' difficulties. Using SSM for analyzing the students' perceived learning system revealed their specific difficulties, while providing a real life example on using the methodology. After understanding the students' difficulties, the course structure was changed for better addressing these difficulties. This paper describes the course, the methodology and the results obtained after implementing the proposed changes to the course.**

***Index Terms*—Soft systems methodology, systems analysis and design, problem solving.**

I. Introduction

The course Information, Systems and Information Systems (ISIS) is part of the Organizational Development and Consulting graduate program. This is an inter-disciplinary program that augments and emphasizes a variety of academic approaches related to several knowledge domains such as behavioral sciences, sociology, management, welfare, etc. The program focuses on theoretical and practical aspects of organizational development and consulting addressing a wide range of organization types and within the organization the various functions and processes. As such the program was tailored to enhance the graduates' knowledge and provide the basic research and management tools required for the job.

The ISIS course is intended to enhance the student capabilities to analyze and improve human, organizational function and process behavior. It concentrates on developing systemic understanding of the organization in a fast moving society, characterized by increasing change and uncertainty. As part of the course the students are exposed to various analyzing methods, starting with Structured Systems Analysis and Design (SSAD) methodologies used in software based projects and up to [1]'s SSM. SSAD is a widely-used systems engineering method which divides the development process into sub-systems, modules, tasks etc. This division creates a better view of the development process and provides a manageable framework for describing the project and dealing with its complexity. However, although software based systems are among the most complex systems known, their behavior is clearly defined. Each operation has a predefined, absolutely predictable behavior and result. For that reason these systems are defined by [1] as hard systems and the thinking required for analyzing these systems is referred to as "hard systems thinking" [1]. On the other end of the scale there are non-engineering systems, such as people oriented systems which their behavior is uncertain and unpredictable. For these soft systems, the hard systems thinking and analysis methodologies are not sufficient. Soft systems thinking and methodologies, required for dealing with soft systems, such as SSM can be applied in Operation Research (OR) and other ill-defined fuzzy problem spaces characterized by the unpredictability of people behavior [2].

Most of the students in the graduate program have prior experience rooted in the social and behavioral sciences. Although a pre-requisite is computing proficiency, no one has professional understanding in software development or modeling. As such the SSAD methodologies are usually more difficult to grasp. This was evident by examining the average grades the student have obtained on the SSAD exercises, compared to grades of the other exercises and as mentioned in the students reflections regarding the course.

This paper describes a study in which SSM was used for identifying the students difficulties related to SSAD. The study was performed by the students and it helped outline their understanding problems as well as enhanced their experience related to the SSM methodology. After the students' difficulties became clear, the course was modifies in order to overcome these difficulties, as was demonstrated by the elevated SSAD exercises grades compared to the previous version.

II. Theoretical Background

The Soft Systems Methodology has been developed over the past four decades by a team of academics from the University of Lancaster led by Peter Checkland in order to deal with unstructured problems [1], [3]. The methodology supports the "Soft Systems thinking" that seeks to explore "messy", problematic situations which in most cases are caused by human activities. Contrary to the SSAD approach that seeks to reduce complexity by dividing the system into smaller manageable pieces that can be modeled (Hard Systems), SSM concentrates on the system as a whole. So

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instead of breaking the systems into its components and examining each one, the SSM seeks to evaluate as many different perceptions that exist in the minds of people involved in the messy situation [4],[5].

SSM is based on a set of seven activities (Fig. 1). The concept behind the methodology uses two main aspects: The problem as it is being perceived in the "real world" and the "systems world". The main analysis and the ideas regarding possible solutions are performed in the systems world, based on the understanding obtained in the real world. These new ideas of possible solutions are brought back into the real world (at stage 5) for a more elaborated understanding about the problem and the feasible solutions [6], [7].

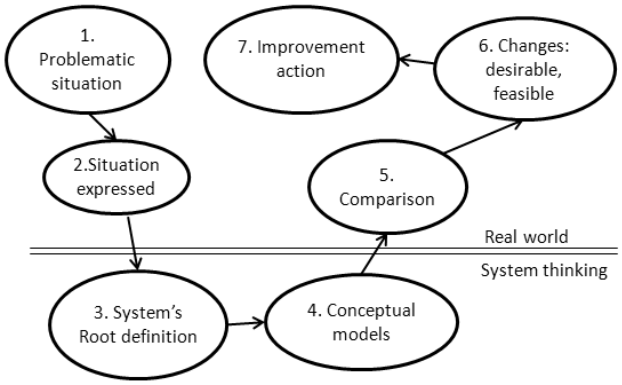

Fig. 1. The SSM model.

The SSM approach, which is based on understanding the context in which the system functions, starts with finding as much as possible about the problematic situation (stage 1). After finding all relevant information and understanding the current context, a rich picture is drawn (stage 2). The rich picture is based on some very basic rules and provides a quick and effective way to deliver wide range of information on the system. The next two stages (3 and 4) represent the main system thinking activities. In stage 3 a root definition of the systems is formulated. The root definition that represents the accumulated understanding about the systems is based on several elements known by the mnemonic CATWOE that define the issues to be considered (Table I).

TABLE I: CATWOE ELEMENTS

CATWOE elements	Description
Customers	Who are the victims or beneficiaries of the system?
Actors	Who makes the transformation happen?
Transformation	What are the inputs and (transformed) outputs?
Weltanschauung (German for World view point)	What makes the transformation meaningful in context?
Owners	Who could stop the transformation process?
Environmental constrains	Which elements outside the system are taken as given?

Based on the understanding gathered and the root definition that was formulated, a conceptual model is built. The conceptual model describes the activities that must take place in order to achieve the transformations that were defined in the root definition. In addition the conceptual model describes how the systems activities will be controlled and monitored. Usually these monitoring and control activities are based on three E's (efficacy, effectiveness and efficiency). Efficacy ensures that the system has a goal to achieve and as long as the goal was not achieved yet, additional transformations are needed. Effectiveness ensures that the system as a whole will achieve its goal (be able to perform the required transformations) and efficiently ensures that the transformations are performed efficiently [8]. The conceptual model (stage 4) is based only on the root definition (stage 3) and does not relate to other real world activities; as such it is a theoretical model that defines what the system will have to do in order to fulfill the root definition. The conceptual model describes a system, with inputs and outputs and especially all inter-related internal activities that are required. These conceptual model activities are represented as verbs [9]. The last three stages (5, 6, and 7) are performed in the real world and consist of mainly a comparison (stage 5) between the conceptual model and what has to be done, to what is actually performed. The differences between the conceptual model and the actual situation highlight the problems. Stage 6 consists of an analysis about the required changes, including special attention to the various aspects such as cultural, political, etc. and after a concrete change plan was defined, stage 7 is the implementation of this plan. These newly introduced changes, may affect the system in ways that were not anticipated so additional iterations may be required. For this reason the SSM is an action research methodology.

Due to its holistic approach SSM has been implemented successfully in many areas and many authors have discussed the methodology and its applicability to business management [10]-[13]. Unlike previous analysis methodologies, such as SSAD, that assume the existence of some formal problem definition, SSM uses an holistic approach which is better suited for dealing with real world management problem situations. In such problem situations different stakeholders often have different, sometimes even divergent views about the problem. The holistic approach exercised by the SSM provides an in depth investigation of the human dimension of the problem, by using the CATWOE based root definition.

III. The Course

The Information, Systems and Information Systems course is intended to elaborate on the issue of organizational consulting and enhance students' knowledge in using various problem solving multidisciplinary methodologies. For better understanding the holistic approach, which provides the foundations for the SSM, the first part of the course is dedicated to the engineering SSAD, which uses an opposite approach. While SSM defines the system models based on various world-views (weltanschauung) that have to integrated in order to produce the necessary understanding, SSAD seeks understanding the details and for that reason the view should concentrate not on the whole systems but on a small piece at a time.

The Organizational Development and Consulting program started in 2009 and it requires two full days of on college

studies. The ISIS course was taught five times already, all of them by the same lecturer. Being a new graduate program the number of participating students in the first four years was artificially limited to about 25. In all five years there was an uneven gender distribution favoring the female students. Table II summarizes the number of students per year.

TABLE II: NUMBER OF STUDENTS AND DISTRIBUTION

Year	Number of students	Female students	Male students
2009	23	21 (91.3%)	2 (8.7%)
2010	27	23 (85.2%)	4 (14.8%)
2011	27	21 (77.8%)	6 (22.2%)
2012	24	22 (91.7%)	2 (8.3%)
2013	36	27 (75.0%)	9 (25.0%)

A. The Course Assignments

The grade in the course is calculated based on five unique and personalized assignments [14]. This type of assignments assures proper learning and concrete students' evaluations, since each student received a different assignment and is responsible for his or her work since it is impossible to borrow ideas or part of the solution from another classmate.

1) First assignment

The first assignment is about understanding the strategic importance of information systems in the organization. Each student receives a link to a software package and has to analyze it usefulness to various organizational functions.

2) Second assignment

In the second assignment each student has to draw a Data Flow Diagram (DFD) to describe a process with several activities. DFD was introduced in the late 1970s as part of SSAD to represent the flow of data from external entities into the system, the flow within the system, between one process to another and the flow from the system to external entities [15]. Although DFD was originally aimed at information systems the methodology can be used to identify business processes as well. In this assignment, the students are using the methodology to draw and explain processes of their choice.

3) Third assignment

The third assignments is about exercising the first two stages of the SSM and the students are required to draw a rich picture describing some problem situation that was provided.

4) Fourth assignment

The fourth assignment is divided into two parts and it relates to the previous assignment (the third one). Here the students have to formulate the root definition that evolves from the rich picture and in the second part they have to define the conceptual model that is developed based on the root definition.

5) Fifth assignment

The fifth and final assignment summarizes the SSM and here the students have to analyze a given situation going through all the seven stages of the methodology.

These assignments can be divided into two distinct groups: one group which consists of first two assignments addresses computing related issues, including SSAD, and the second group which consists of the rest three assignments addresses SSD issues. In the first year the course has been taught there was a large difference between the average grades of the two groups of assignments. Group one average was 76 while the second group's average was 87. The average grades for the assignments within the group were very similar. For the first group, the average grades for assignments one and two were 76 and 75 respectively. For the second group the averages for assignments three, four and five were 87, 88, 87 respectively. Although the difference could be explained by the students' prior experience, since all are from social and behavioral sciences. However in spite many discussions and analyzing the students' reflection, it was not clear what exactly is causing this misunderstanding related to the computing discipline. For the second year, a reference manual was written, with all relevant learning materials, however it did not help. So in the second year, when the average grades for the first group remained relatively low (75), this study was initiated.

IV. THE STUDY

The main idea behind this study was to identify the cause for the low grades in the assignments that address computing issues, so corrective action could be planned. Since SSM is widely used for investigating messy situations helping better understand the system while considering many view points, it was chosen for the study. After the problem repeated itself in the second year, it was time to involve the students in the definition of their "system". The system here refers to the course and the problematic situation regarding the assignments in the first group. In this case the students assumed the role of the clients, who use the system as well as the analysts that are developing the conceptual model and suggesting the feasible changes. Success here can be defined by decreasing the difference between the average grades of the two groups of assignments. Being an action research, due to using SSM, this exercise will repeat itself until the anticipated results will be achieved. This means that if after implementing the changes, the difference will still be significant, next year an additional analysis will be performed, suggesting additional changes to the system and so on. There was an additional hidden benefit in using the methodology and it relates to a real world example on how SSM can be used by actively exposing the students to the process. This hidden benefit however was not measured, since the original grades in the second group of assignments were sufficient.

After learning the SSM the students were engaged in a class exercise for defining the conceptual model for the course. Each student had a slightly different approach and definition, however, after a short moderated class discussion, the following agreed upon students' view CATWOE definition was reached (Table III)

The root definition which was formulated based on this CATWOE was: "This course is a system that provides knowledge for the students and allows them to fulfill the requirements in the path to obtaining the degree. The degree is what future potential employers are looking for in hiring new employees. In providing this knowledge, special

emphasis should be given to new subjects, such as SSAD, since these were not previously learned or required during enrollment to the program. The system must be able to perform the transformations within constrains imposed by laws and regulation and provide a study format flexible enough to help students meet their time requirements in other courses, as well as their work, social and family commitments."

TABLE III: STUDENT CATWOE DEFINITION

CATWOE elements	Definition
Customers	Students
Actors	Lecturers, students (in teamwork and in class discussions)
Transformation	Extending knowledge related to organizational consulting using various methodologies. Specifically "new knowledge" from unfamiliar disciplines like SSAD
Weltanschauung	With the degree graduates will be able to find better, more interesting jobs and increase their salaries. The potential employer is looking for a specific degree and since this is a mandatory course, it is required for obtaining the degree
Owners	Department head, college management
Environmental constrains	The higher education counsel (that monitors all academic studies), academic excellence, college regulations, other courses, work and family

This root definition starts to reveal some of the difficulties students faced related to the SSAD methodology and the computing issues at large. The time constrains were addressed clearly and demonstrated the fact that students were limited in the amount of time they could spend on learning and that this time had to be divided among other courses as well. Furthermore, it was clear in the discussions and it is expressed in the root definition, that when addressing new knowledge, for example computing related, the student felt they needed more rehearsal and more moderated exercises.

The next step in implementing the SSM was drawing the conceptual model, which defines a set of activities required for achieving the root definition. There was a long debate and many discussions among the students regarding the required activities that are presented in Table IV and at the end an agreed upon model was selected (Fig. 2).

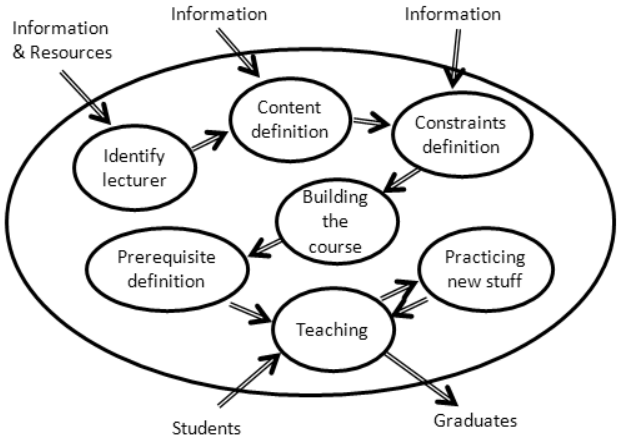

Fig. 2. The course conceptual model.

TABLE IV: THE COURSE CONCEPTUAL MODEL

Activity	Description
Identify lecturer	For some reason it was important for the students to start with identifying the course lecturer. For doing so, they thought additional information is required, such as a list of available and capable lecturers.
Content definition	After the lecturer was identified, the course content has to be defined. This required additional external information, such as the overall program aims and how this specific course supports these aims.
Constrains definition	The constraints definition triggered a long discussion among the students. Some suggested it should be part of the content definition, since defining the content has to consider the constrains as well, while other disagreed, mainly due to the fact the studies are during two days and all students have additional commitments (work, home, social, etc.) To stress the importance of the constraints it was agreed it deserves an activity by itself.
Building the course	After the lecturer was identified, constraints and content are clear, the course can be developed.
Pre-requisite definition	Based on the content to be taught (as part of the course that was developed in the previous activity), the students pre-requisites can be defined. The issue was discussed mainly due to the fact that the first part of the course relates to subjects most students were not familiar with. Some students thought that a pre-requisite stating that the program is intended only for students with previous information systems experience should be added, however it was ruled out by the majority of the students.
Teaching	The actual course delivery, as it was performed. This activity has an external input - the students and produces an output - the course graduates after completing all requirements as defined in the previous activities (content and constraints definition).
Rehearsing new stuff	This was a new activity suggested, which shed light on the problems students had with the computing related issues. The agreed solution was that when addressing the "new stuff", which is not known by most students, more in class rehearsal, is required.

The last activity defined was very interesting, since in the previous year the students' reflections revealed a problem, however the students did not elaborate on the causes. The active students' involvement in formulating the root definition and later defining the conceptual model required them not only to think about the problem, but also suggest a way to correct it.

The conceptual model that was drawn (Fig. 2) reflects the activities including their order. The large ellipse is the problematic system and the smaller ellipses are the various activities to be performed. Arrows going into the system represent inputs (information, resources, students), while arrows going out from the system represent output (course graduate).

It is worth mentioning that as part of the action research the SSM requires additional monitoring activities to the system and taking corrective action if the anticipated results were not achieved, however in this study, the students were nor required to define these monitoring activities since they were performed as part of the study itself without the students' involvement.

Based on the understanding obtained from the students'

conceptual model, a change was introduced to the course structure. The exercise of using SSM for analyzing the course itself became a standard practice. In addition, each of the students' assignments was assessed by an additional student. This means that each assignment was prepared by one student and later assessed by another. The student not only was involved with his/her assignment but was also exposed to another classmate's thinking. This was possible due to the fact that each student got a personalized unique assignment different from his/her classmates' assignments. The additional rehearsal proposed by the student in their conceptual model was achieved by reviewing work performed by another student.

The monitoring activities that usually appear in conceptual models, and were omitted here, were addressed as part of the study and not the course conceptual model. The success or failure of the proposed changes in the course structure was measured as the difference between the average grades of the assignments in the two groups.

V. Results and Discussion

The first two years the course was taught (2009, 2010) there was no special emphasis on the computer related abstract issues in the first half of the course. Due to the fact these were new issues for all students, far from their prior studies or experience, the average grades obtained was relatively low (Fig. 3).

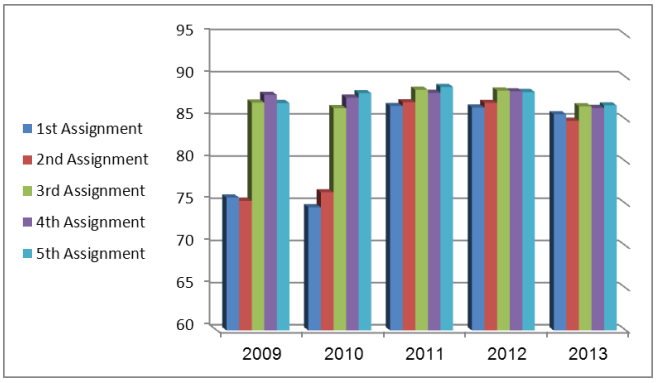

Fig. 3. Average assignments' grads.

Based on the students' conceptual models, which revealed their insight and difficulties related to the computing issues and the course structure changes that follow, the problematic situation improved significantly. In the following three years (2011, 2012, 2013) there was no real difference between the grades of the two groups of assignments.

The additional needed rehearsal, which was reflected in the students' conceptual model, was achieved by the peer review (the additional assessment performed by each student). Peer review is a form of external evaluation carried out by professional colleagues [16]. Peers can be experts in the field they assess but can also be classmates who review the work of fellow students. Peer review is a widely practiced in certifying quality in higher education [17], but also encourages critical examination and promotes the exchange of ideas' which promotes learning [18]. Being aware of the advantages of peer review, it has been incorporated in the course to enhance the students' understanding regarding the more abstract computing issues. This change has a very positive effect, since it managed to reduce the grades difference. This study enhances previous researchers work in using the peer review process as an additional learning mechanism.

Furthermore, SSM is an action research process that sometimes is performed in several analysis cycles. After the change suggestions have been accepted and applied to the system, sometimes new problems arise or the anticipated improvement is not sufficient. In such cases a new cycle of analysis is performed. In this study, the original intention was to utilize the same mechanism and apply several cycles of analysis and changes, however as can be observed from the results obtained, there was no need for additional cycles.

The study had an additional hidden objective, to enhance students understanding regarding the SSM processes in applying the methodology to a real life situation. For the first time the conceptual, model was developed, (second year of the course) the problems associated with understanding the more complex issues of SSAD were very realistic, so the model included the rehearsal activity. In the next years the conceptual model was developed and due to the assessment that was in place, the students' perception regarding the rehearsal activity changed and in the later conceptual models student did not feel anymore it is required, so it was omitted from the model, as can be seen in Fig. 4.

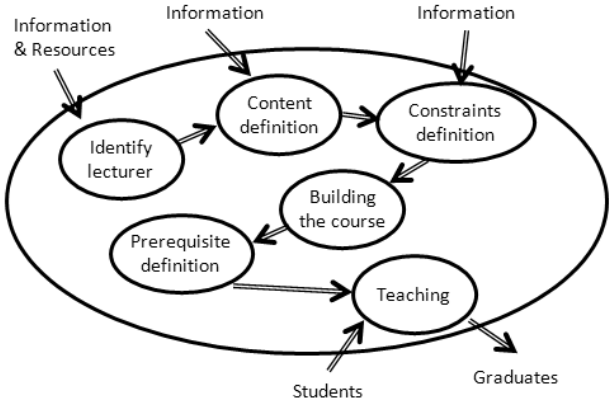

Fig. 4. The course conceptual model (later versions).

There were some additional minor differences between the first model and the other ones, for example relating to the identification of the lecturer (in the later version, this activity was omitted however these differences do not affect the study). The hidden objective of providing this real life exercise was not measured as part of this study, since the original grades obtained in the second group of assignments was sufficient.

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