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# Using Critical Systems thinking to Improve Student Performance in Networking

Albertus G. Joubert, Roelien Goede

***Abstract*—**This paper explores how Critical Systems Thinking and Action Research can be used to improve student performance in Networking. When describing a system from a systems thinking perspective, the following aspects can be identified: the total system performance, the systems environment, the resources, the components and the management of the system. Following the history of system thinking we observe three emerged methodologies namely, hard systems, soft systems, and critical systems. This paper uses Critical Systems Thinking (CST) which describes systems in terms of contradictions and conflict. It demonstrates how CST can be used in an Action Research (AR) project to improve the performance of students. Intervention in terms of student assessment is discussed and the impact of the intervention is discussed.

***Keywords*—**Action Research, Computer Networks, Critical Systems Thinking, Higher Education

## I. Introduction

THE aim of this paper is to demonstrate how Critical Systems Thinking (CST) and Action Research (AR) can be used to improve student performance in Networking. Information and Communication Technology (ICT) students at the Vaal University of Technology takes two modules in Computer Networking as part of their academic program. Many of the graduates of this program find positions in the computer networking industry. The performance of students in the Networking modules is not satisfactory. This paper explorers CST as a methodology for guiding improvement in this situation.According to [1], a system is a set of parts coordinated to accomplish a set of goals. When describing a system the following aspects can be identified: the total system performance, the systems environment, the resources, the components and the management of the system.

Systems Thinking emerged as an reaction to reductionism when [2] advocated an interdisciplinary approach to problem solving. Different methodologies developed. This paper uses Critical Systems Thinking (CST) which describes systems in terms of contradictions and conflict. This paper demonstrates how Critical Systems Thinking (CST) can be used in an Action Research (AR) project to improve the performance of these students.

The paper starts with providing some background of the problem situation. A short introduction of CST is given to provide background. The remainder of the paper is organized according to the phases of the AR project: Diagnosis; Planning and intervention; Advise Improvement; and Analyze success of intervention of the AR project. The paper concludes with a summary of results.

A.G. Joubert is with Vaal University of Technology, Vanderbijlpark, 1900, Republic of South Africa (e-mail: joubertb@vut.ac.za).

R. Goede is with North-West University, Vanderbijlpark, 1900, Republic of South Africa (e-mail: roelien.goede@nwu.ac.za).

## II. Background

After completing two years of academic training, Computer Systems engineering students at the Vaal University of Technology (VUT) do their compulsory in-service training at companies in the Information and Communication Technology (ICT) industry. These students have to be visited by lecturers as part of the monitoring system. During these visits the lecturers realized that all networking student are send on Cisco courses early in their practical period, in order to give them more practical exposure and specialist knowledge before sending them into the work place. This tendency led to an investigation into the possibility to include the Cisco training as part of the main stream course. This will make the students more marketable, since companies save money and time and have a student that could immediately start being productive.

The Cisco Certified Network Associate (CCNA) Discovery curriculum provides general networking theory and practical experience. The course is based on application, covering networking concepts within the context of network environments that students may encounter from small office and home office (SOHO) networking to more complex enterprise and theoretical networking models later in the curriculum.

In 2009, the program was implemented at the VUT, where the Department of Computer Systems started to operate as a local Cisco academy. Several of the academy program courses were integrated into the ICT and Computer Systems Engineering Diplomas offered at the Vaal University of Technology.

The requirements for the module are basic computer literacy skills, foundational mathematics and problem solving skills. The curriculum offers a learning experience for more visual and kinetic learners. Many interactive activities are embedded in the courses to help reinforce student comprehension. The large number of laboratories encourages additional hands-on practice. Regardless of these efforts examination marks indicate that the students still performed poorly in the theoretical parts and even worse in the in the practical parts of the curriculum.

The poor performance of the students in these CISCO examinations motivated the lecturers to start a research project in order to improve the marks of the students.

## III. Research Method

As the goal of this research project is improved student performance and the researcher is able to intervene, action research was chosen as research method. Quantitative and qualitative methods will be used in different phases of the AR project. According to [3] action research aims at understanding an immediate social situation; assists in practical problem solving; expands scientific knowledge; and is primarily used for the understanding of change processes in social systems. Thus the reason for choosing action research for this research is because a real complex problem needs to be solved, true participation and collaboration will take place, action will be enabled and a contribution towards knowledge of theory and practice are foreseen.

Action research is a cyclic process, consisting of the following phases: diagnoses, plan and implement of intervention, analyze success of intervention and advice improvements.

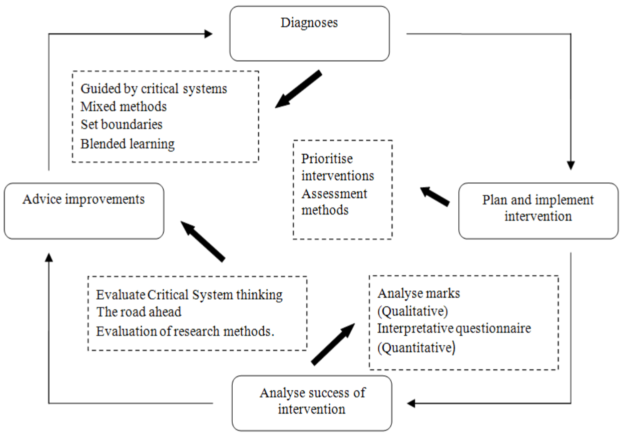


Fig. 1 Schematic layout of action research

Fig.1 is a representation of the AR process followed in this project. The aim of the diagnosis phase of the project is to better understand the problem situation. The research team decided to use Critical Systems Thinking Heuristics (CSTH) of Ulrich, as this provides a method for holistic understanding of a problem environment. This paper will only report on the first phase of the AR process. The rest of the paper is organized according to the phases of the AR process. Prior to discussing the diagnosis phase some background information on CST is provided.

## IV. Critical Systems Thinking

The basis for natural science has three fundamental principles namely, reductionism, repeatability and refutation. From this it is clear that natural scientists research a reduced part of the whole phenomena, which is separate from the whole. In contrast to this approach is system thinking, which is less reductionist and more holistic, and where the system refer to inter-connected elements that forms the whole. This holistic approach embraces complexity through the properties of the whole and related properties that is only present at the level of the whole. It can thus be said that system thinking is a way of interpretation of the interconnected elements in relation to the whole [4], [1].

Following the history of system thinking we observe three emerged methodologies namely, hard systems, soft systems, and critical systems. Hard system thinking incorporates operational research, system engineering and system analysis.

Hard system methodologies are not designed to understand systems, their focus is on change and improvement of systems [5]. The system exists independent of the observer, thus the engineer or analyst intervene the system, while standing outside it. Human beings in a hard system are treated just like component parts and organizations are treated like machines.

Beyond hard systems and Popper's idea of falsification and resistance to hypothesis falsification, is a second paradigm called soft system thinking. Its theory is related to human affairs and it is appropriate to deal with problematic situations [4]. Soft systems thinking advocates that people have different viewpoints which are all regarded as legitimate and lead to the discovering of different perceptions of reality [6]. Soft systems have a limited domain in which they can operate effectively. They tend to neglect moral and ethical judgment.

According to [5] an approach based on the critical theory of Habermas is necessary to understand the contradictory nature of some of the social systems. The critical system thinking approach originate from the work of Habermas [6]. The basic idea of critical system thinking is that the world is constantly changing and to understand, explain and control these changes we must think in terms of contradictions [7]. Contradictions could be made explicit and its perspectives could be negotiated, but unless they are tested in practice their meaning will not be revealed and they will not be understood properly. The idea of practice is to understand contradictions through intervention and action [7]. Critical system thinking is the methodological approach that will be followed in this research and the practice of action research will lead to intervention and action.

## V. Diagnosis Phase of AR Project

The aim of the diagnosis phase of this project is to better understand the problem situation. The research team decided to perform critical boundary judgment according to the boundary questions of [8]. The questions and the analysis of the situation according to the questions are given in Table 1.

TABLE I
Boundry Judgement

| Question | Analysis |
|---|---|
| Who ought to be the client (beneficiary) of the system S to be designed or improved? | Students and Industry |
| What ought to be the purpose of S; i.e. what goal stated ought S be able to achieve so as to serve the client? | The students should be prepared in such a way that they are competent in performing computer networking tasks as required by industry. |
| What ought to be S's measure of success (or improvement)? | If the industry partners are satisfied and the students perform satisfactory in the CISCO network modules. |
| Who ought to be the decision taker, that is, have the power to change S's measure of improvement? | The head of department of Computer Systems Engineering supported by the module owners at the VUT. |
| What components (resources and constraints) of S ought to be controlled by the decision taker? | External (CISCO) evaluation instruments as resource and constraint. |
| What resources and conditions ought to be part of S's environment, i.e. | The specific network platform; The summative evaluation instruments |

| | |
|---|---|
| should not be controlled by S's decision taker? | of CISCO; the background of the student; Budget constraints. Current staff qualifications. |
| Who ought to be involved as designer of S? | The module owners at the VUT; past students, Industry representatives; |
| What kind of expertise ought to flow into the design of S; i.e. who ought to be considered an expert and what should be his role? | Pedagogical knowledge; Computer Networks knowledge; The module owner should guide the process to include other stakeholders. |
| Who ought to be the guarantor of S; i.e. where ought the designer to seek the guarantee that his design will be implemented and will prove successful, judged be S's measure of success (or improvement)? | The head of department of Computer Systems Engineering supported by the module owners at the VUT. |
| Who ought to belong to the witnesses representing the concerns of the citizens that will or might be affected by the design of S? That is to say, who among the affected ought to get involved? | Current Students; Past students; Employers; CISCO representatives. |
| To what degree and in what way ought the affected to be given the chance of emancipation from the premises and promises of the involved? | The students should adequately be prepared for industry. Instead of relying on the lecturer to decide the content, CISCO's training material and assessment instruments are used. |
| Upon what world-views of either the involved or the affected ought S's design to be based?" | The view that the material of CISCO is representative of the needs of industry. |

As a first step the current pass rate of the module was analyzed. Every module has a practical as well as a theoretical part that the students must pass in order to pass the module. The pass rate is 48% and the students perform poorly in both the practical and the theoretical assessments. A qualitative analysis was done using an open ended questionnaire that was completed by 60 students in order to identify the aspects of the modules that they struggled with most. Of the 60 students 43 indicated that they struggle with the practical application and 31 indicate that the sub-netting was very difficult for them.

From the CTSH analysis presented in Table 1, it is clear that past students as well as industry may be involved in decision making on matters to improve students' performance. This process will take a semester or two before implementation of improvements can be done. In the meantime one has an obligation to the current students to make some short term changes that may benefit them. After discussions with stakeholders it was decided to first focus on expanding the assessment instruments to formative evaluation conducted in the modules.

Following is a diagnosis of the formative evaluation of the module as currently presented.

Every chapter in the module has Packet Tracer simulation exercises that the students must complete before doing the practical on the physical equipment. These Packet Tracer exercises are assessed and form part of the formative assessment. These exercises are evaluated by the simulation program as the students continue. The students can thus see how the marks accumulate towards 100%. There is also an online rubric available that the students could select at any point to see what they have done right up to that point and what is wrong. The students could go back and rectify errors and do the omitted configurations until the assessment mark is 100%. The students get use to using a rubric in order to complete their practical assignments. This method of testing and helping the students prevent them from holistically thinking about the network that they are busy with. They also do not critically analyze what they are implementing. Apart from supplying a rubric the instructions were given step by step. The students could just follow the steps, without thinking about the logical sequence of solving the problem and setting up a network. All formative assessments are done this way.

This way of setting up network systems brings the students under a false impression of how it is done in the real work situation and what is expected of them during the summative assessment.

## VI. Planning and implementation phase of AR project

The summative practical assessment, of which the lecturers do not have control, does not include a rubric and also do not indicate any marks to show progress. Instead of step by step instructions the summative assessment just focuses on the final outcome of each section. The students are suddenly placed in an unknown situation where they don't have an idea what is wrong if their network communication failed. They are not used to do fault finding using critical analysis. The rubric can thus be seen as an oppressing factor instead of the intended help. As a first step to have some immediate impact, it was decided to change the method of formative assessment of the practical exercises.

New Packet Tracer practical exercises were developed by lecturers. These formative assessments were in line with the summative assessment. The students thus get used to do critical analysis and to trust their own judgment instead of relying on a rubrics and a step by step guided approach to solving network problems.

According to Ulrich the purpose of a system should be to the achievement of the goals in order to serve the client. In this cycle the students as well as industry as stakeholders is served through a process of critical thinking and analyses of a practical situation.

## VII. Analyze success of intervention phase of AR project

The participants for the quantitative analysis included the students of six network classes. The intervention took place in three network groups with a total of 69 students. All students involved had the same lecturer. The practical marks of three groups (total 66) that completed the course during semester 1, 2011, without intervention, was compared to three groups (total 69), semester 2, 2011, where the intervention took place.

The data that was used for the analysis consist of the online practical marks that the students obtained during their summative assessments. Data analysis was done using descriptive analysis. The data was entered into a spreadsheet and plotted on a graph.

The two graphs in figures 2 and 3 show that there were a significant improvement in the practical marks of students from Semester 1 – 2011 to Semester 2 – 2011. Semester 1 – 2011 had an average of 29.59% with a standard deviation of 14.34 while the average of Semester 2 2011 increased to 58,74% with a standard deviation of 14.51.

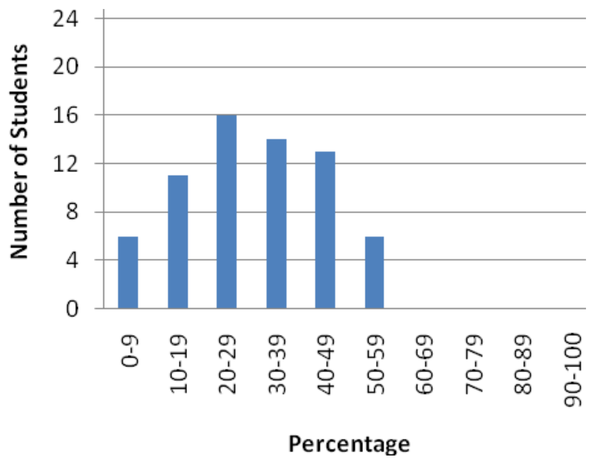


Fig. 2 Student marks for semester 1, 2011

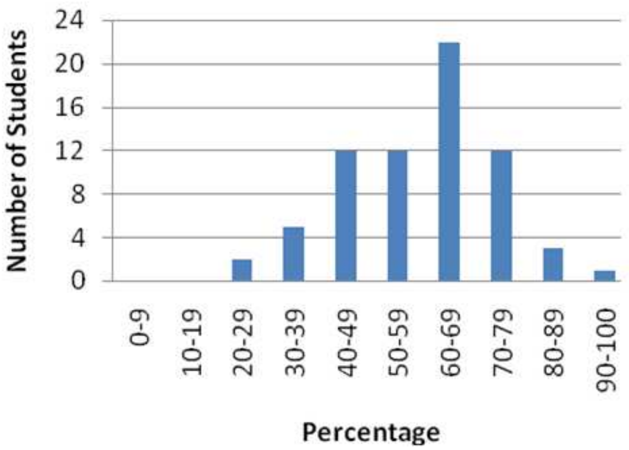


Fig. 3 Student marks for semester 2, 2011

## VIII. Advise Improvements Phase of AR Project

Although there is some improvement in the practical marks, it is not good enough, since the students must obtain 70% for the practical component of the course and 60% for the theoretical component of the course. The question could be asked whether this method of formative assessment should be continued with and the answer is yes.

The second cycle of this AR project will focus on the sub-netting part of the curriculum, since the ability to sub-netting a computer network influence the practical as well as the theoretical components. Thirty one of the sixty students that completed the open-ended questionnaire indicated that they have problems understanding the concept of sub-netting. To be in-line with Ulrich's question of what components of the system ought to be controlled by the decision maker is was decided to attend to the following factors in the second cycle of this AR project: the module content; the method of instruction; the resources used in the instruction.

## IX. Conclusions

Critical system thinking has the ability to approach the problem as part of the whole system. It does not only react to one part of the system, but take into consideration the whole system and the influence of the problem on the whole system.

The method of formative assessment thus influenced the whole program and by intervention in a positive manner could be one of the factors leading to an increase in the practical marks of the module. The intervention is however not completed and the twelve questions posed by Ulrich must be constantly part of the process in order to be aware of the boundaries of the system. Since AR is a cyclic process this project will be continued with focusing on the sub-netting part of the curriculum.

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