The Application of Logical Tools in Project-Based Classrooms

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***Abstract*:** The purpose of this paper is to investigate the application of logical tools such as inference trees and columnar data flow diagrams in the information system (IS) analysis and design context. Seventeen students at an institution of higher education were observed during the design and analysis of information systems and their experiences were evaluated through a focus group interview, observations and documents analysis. This research was based on a qualitative, action research approach (Yin 1994; Merriam 1998). The most important findings were: the columnar method empowers students' motivational and cognitive skills enhancing their vision and system design skills; inference trees improve detection and correction of reasoning errors overcoming students' limited information processing capacity.

***Keywords*:** columnar data flow diagram, inference tree, complex arguments, reasoning errors, instructional program

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1 Introduction

Mende (1988a) suggested that a data flow diagram could be drawn so that components with similar functions would appear in the same column. Mende (1987,1988a) proposes the structured tool, the *columnar data flow diagram* (CDFD) as the reader can visually assess the *power* of the system. The designer of a *data flow diagram* should group like with like … if the components of the diagram were placed randomly, readers would have difficulties with finding what they are looking for (Budgen, 1994; Mende & Mohamed, 1999; Shoval 1991; Kabeli & Shoval, 2001; Shoval & Sadan, 2002). Random and hierarchical placing of components in a standard data flow diagram (SDFD) result in difficulties in reading, checking and drawing of diagrams. This in turn could influence a fragmented knowledge, low motivational and creative involvement of students during information systems design tasks (Powers, Cheney & Crow, 1990; Jakovljevic, 2002).

Information systems analysts often write descriptive reports and they sometimes need to write complex, expository reports. The reports serve as a basis for the project releases discussions. Practice shows that reasoning errors occur during the project discussions as well. Analysts very seldom use keywords such as 'so' or 'therefore' during the analysis process or they use them in a wrong way (Mende, 2006, Jakovljevic, 2002). These kinds of reports and discussions contain different kinds of reasoning errors (for example, efficiency and effectiveness errors) preventing analysts from connecting interrelated elements into a 'system' (Mende, 2005a, 2005b). Therefore, analysts need skills in logical thinking which is expressed in the ability to create clear arguments and connect interrelated elements into a 'system'.

Students as information systems analysts very seldom use the keywords such as 'so' or 'therefore' during the process of analysis or they use these keywords in a wrong way (Mende, 2006, Jakovljevic, 2002). To avoid those errors, students ought to pay more attention to the system of core ideas and inferences. For that purpose they need a tool which isolates the core ideas from the peripherals in each paragraph and emphasizes the inferences between core ideas. One such tool is the *inference tree* (Mende, 2005a, 2005b). The researchers share the opinion that a logical tool such as the inference tree can help to detect logical errors during the IS analysis process.

Many investigations are still necessary to determine whether these logical tools (CDFD and an inference tree) can actually be realized in a wide variety of real-life environments (Mende, 2006). Although a conceptual rationale suggests that these tools should be very widely applicable (Mende, 2006) too, few examples are given to provide conclusive evidence with regard to motivational and cognitive applicability in a project-based classroom.

The present paper explains now how systems analysts and designers can use the CDFD and the inference tree to improve their logical thinking, and therefore contribute to better systems analysis and design outputs. Furthermore, the paper explains how these tools can be better utilized if they are integrated within an instructional system, the Instructional Web Designed Programme (IWDP).

Therefore, the purpose of this paper is to investigate the role of these logical tools in a project-based classroom, based on the powerful conceptual framework (Waters,1974; Weinberg, 1980; Mende, 1988, 2006; Mende & Mohamed, 1999).

Based on the above mentioned discussions the following research questions have been addressed in this paper:

(1) *How does the application of columnar data flow diagrams influence students' cognitive, motivational and system design skills?*
(2) *Why is the inference tree the appropriate tool for systems analysis?*

The first section presents a conceptual framework on logical tools and the ELIP, so that the rationale for empirical research can be understood and properly interpreted. It is followed by findings and discussions, which will lead to the conclusion that logical tools such as a CDFD and an inference tree are powerful tools for systems analysis and design.

2 Framework for the application of logical tools in the project-based classroom

The structured model of an information system in a columnar form: CDFD

An information system can be represented in a columnar form, which has the following characteristics (See Figure 1):

- The central column contains the permanent data stores.
- the first three columns from left to right contain sources, data inflows, and processes that collect inflows into the stores.
- the last three columns from right to left contain users, information outflows and processes that extract information from the stores (Mende & Mohamed, 1999). (See Figure 1)

Figure 1: Typical structure of an information system using CDFD

Since people normally read from left to right, the flows between the groups should be from left to right (Mende & Mohamed, 1999). So the columns should be drawn in sequence from sources through data collection, stores, extraction and information to the users. Therefore, the structural model (Figure 1) now predicts that designers can draw the top-level data flow diagram of many information systems in seven columns.

The columnar data flow diagram has at least four advantages:
1. If a reader is trying to understand individual components of the system, then the column position of each component immediately identifies the function of that component.
2. If a reader is looking for a particular kind of component, say an inflow or a collection process, then he or she can quickly find it by searching the relevant column.
3. If a reader needs an overview of the system's information outflows and data inflows, then he or she can simply scan the data and information columns.
4. Most importantly, a reader can easily assess the *power* of the information system. (Mende & Mohamed, 1999).

Boden (1990) suggests that *vision* is the most powerful human sense, having evolved to notice spatial relations such as connectedness, juxtaposition and gaps. A columnar data flow diagram is particularly useful for detecting *gaps* – i.e. design omissions in the pattern of flow from sources of data through collection, stores, extraction to information and users (Mende & Mohamed, 1999).

Practice in project-based classrooms indicates that many gaps exist during complex arguments construction that are leading to unclear business requirements specifications.

There is a need to improve arguments construction skills with a help of an inference tree.

An expository argument

An *expository argument* is a system of inferences between core ideas. An example appears in box 1, where a short argument aims at convincing writers to use inference trees. The argument spreads over 9 paragraphs, whose core ideas are italicised, and it involves three inferences whose inferential keywords are in bold type (Mende, 2002b, 2006).

The three inferences establish inter-paragraph connections:

- the first inference inputs the cores of paragraphs 1 and 2, and outputs the core of paragraph 3
- the second inference inputs the cores of paragraphs 4 and 5, and outputs the core of 6
- the third inputs the cores of 3, 6, 7and 8, and outputs the core of 9.

Box 1: An expository argument (Mende, 2006)

	An expository argument
1.	In an expository report, *inferences may have errors of* relevance that cast doubt on the conclusions.
2.	The *inferences may* also *have mismatch errors* that cast doubt on the conclusion.
3.	**So** *an argument may have effectiveness errors* that cast doubt on the conclusion.
4.	Furthermore, some *inferences may be overloaded*, so that the reader cannot easily understand them.
5.	*Inferences may* also *be belated*, so that the reader may have forgotten the inputs by the time he or she reaches the outputs.
6.	**So** *an argument may have efficiency errors* that make it unnecessarily difficult to understand.
7.	A reader rejects a report that has effectiveness errors, and soon stops reading a report that has efficiency errors. So *writers should avoid these errors*.
8.	*Inference trees can help writers avoid these errors*. The omission error is easy to detect because inferences usually require two or more inputs.
9.	**Therefore** *writers should draw inference trees*.

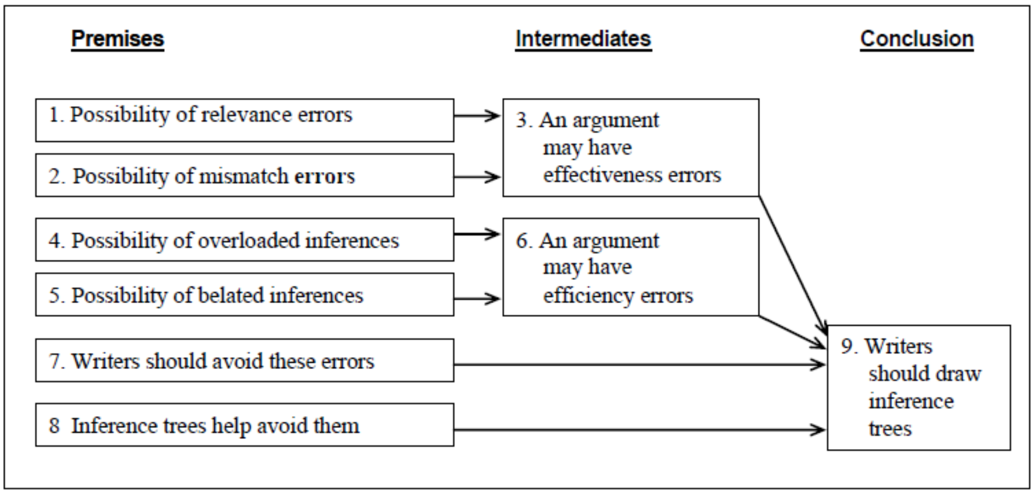
Inference tree: minimizing inefficiencies in human logical thinking

Expository arguments are not easy to devise. The main reason is that the human short-term memory can only accommodate 7±2 ideas (Miller's law) (Baddeley,1993). Thus, they cannot clearly see how all the core ideas are interrelated and lead to reasoning errors that occur easily (Mende, 2006; Govier, 1997). To avoid those errors, students need to pay attention to the system of core ideas and inferences in a text with the use (help) of the inference tree. (See Figure 2).

The core ideas are grouped into three classes, each in a different column of the diagram:

- *Premises* are core ideas in the left-hand column: they are not inferred from other core ideas of the argument, but other core ideas are inferred from them.
- *Intermediates* are core ideas in the middle column: they are inferred from other core ideas and other core ideas are inferred from them.
- *The conclusion* is the core idea in the right-hand column: it is inferred from other core ideas, but no other core idea is inferred from it. (Mende, 2005, 2006).

Figure 2: Inference tree of Box 1 (Mende, 2006)



So an expository argument is a tree of inferences, from premises through intermediates to the conclusion. When writers draw an inference tree of an expository argument, they may find many different kinds of reasoning errors (Mende, 2006): errors of relevance, missing the point, invalid inference, inadequate inference, mismatch, begging the question, circular reasoning, hasty generalisation, overloaded inference, irrelevance, redundancy, omitted inference, belated inference, premature inference, incoherence and inconclusiveness (Mende, 2006).

At the broadest level of classification there are reasoning errors such as effectiveness errors and efficiency errors:

- *Effectiveness errors* cast doubt upon the chain of reasoning, from premises through intermediates to the conclusion, resulting in a reader's lost of confidence in the conclusion.
- *Efficiency* errors create unnecessary difficulties in understanding the chain of reasoning, so that a reader would waste time reading the expository report (Mende, 2006).

The purpose of these logical tools is to visually depict procedural knowledge pathways and to extend students' conceptual and procedural knowledge in general (McCormick, 1997; Jakovljevic, 2002).

Thus, there is a need to teach systems analysts logical skills and arguments construction skills with the help of the inference tree as a logical tool. If these tools are applied in an organized instructional environment the positive motivational outcomes will be visible.

To achieve this purpose and to explore the influence of logical tools on students' motivation, logical thinking and understanding of system analysis processes, an Outcome-Based (OBE) and the instructional web design programme (IWDP) was designed and implemented in the project-based classroom.

The instructional web design programme (IWDP)

The IWDP was based on the three pillars of the theoretical framework: mind tools; higher-order thinking; learning theories, instructional models and strategies (Throwbridge & Wadersee, 1998; Jakovljevic, 2002).

The following components of the IWDP have been identified: Theme; Critical and Specific Outcomes (COs, SOs); Range Statements (RS), Assessment criteria (AC); Performance Indicators (PI), Stages of the technological process: (brief design; Investigation; Proposal; Initial ideas; Research; Development; Planning; Realisation/Making; Testing, Evaluation and Improvement); Students' tasks (case study, resource and capability tasks); Students' on and off-line activities; Facilitator's activities (Instructional strategies), Notional time (Ankiewicz, De Swardt & Stark, 2000, 2001; Jakovljevic, 2002; Reddy, Ankiewicz, De Swardt & Gross, 2003).

The subsequent sections give explanations of the research design and results of the empirical research.

Within an organized instructional environment provided by the IWDP, students were instructed how to use logical tools to improve their motivation, logical thinking, systems analysis and design skills.

3 Research design

Research approach

This research can be described as a qualitative, evaluative case study seeing that the learning experience of students' is being investigated in relation to a specific event in a bounded context (Creswell, 1994, Yin, 1994; Merriam, 1998). The qualitative approach was adopted for this study, as it is particularly suitable for studying phenomena in which little previous research has been conducted (Walsham, 1995; Merriam, 1998). Multiple methods of data gathering and analysis were used to achieve the highest measure of reliability possible within a given method.

Action research was also applied in order to simultaneously create and investigate changes in the use of logical tools in the project-based classroom. The urgency of improving outcomes such as analysis and design skills during the systems analysis and design tasks necessitates an activist research paradigm (Baskerville & Wood-Harper, 1996).

Profile of the students, intervention and setting

In this study seventeen students from mixed cultural groups were identified, at a tertiary institution in South Africa. The students' were grouped into five teams, with three students in a group. Participants presented a purposive convenient sample as they were readily available and inexpensive to this study (Creswell, 1994).

The researcher of this study coordinated the design and development of projects in a form of web sites in duration of one semester in a laboratory at a tertiary institution. Students had to submit five deliverables (project proposal, high-level analysis, detailed analysis and design, prototype and a final system) at a defined time frame. The instruction was based on the IWDP highlighting the use of innovative logical tools. The CDFD and inference tree were explained to students during the systems analysis and design tasks.

Collecting data methods and analysis of data

The primary data was collected by means of a focus group interview and the hybrids of formal interviews (dyadic interviews; group discussions). Informal discussion-type interviews yield data that are easy to align with observation data. The interviews were conducted in order to explore and identify categories and the core aspects relevant to the use of logical tools.

The systems analysis and design processes were *observed* in formal and informal observation sessions. The researcher was present at different team meetings, in order to observe, record discussions and events in observational protocols. Furthermore, all available artefacts/documents produced were utilized for analysis. These include reports for project releases discussions, final reports, documents/outcomes of five deliverables, agendas, design figures, reports from meetings, etc.

Analysis of data consisted of examining, finding patterns, themes and constructing categories (Yin, 1994; Merriam, 1998). A constant comparative method was applied which includes comparison of data within interviews and between interviews (Merriam, 1998). Necessary preparations were performed to improve essential competence in the field, which included the clarification of biases and assumptions (LeCompte, Preissle & Renata, 1993; Creswell, 1994).

This study is characterised by the use of two different data sources, the facilitator and the students, and multiple data gathering methods. In addition, according to the peer/colleague examination and the researcher's awareness of biases, these aspects of data collection and analysis contribute to the reliability of this research (Kerlinger, 1992; Creswell, 1994; Yin, 1994). A rich and extensive description of the phenomena that is studied, contributes to the external validity of this research. (Merriam, 1998)

The next sections endeavor to present the evidence based on *students' and the facilitator's experience* of the CDFDs and inference trees gathered through the focus group interview, informal discussion-type interviews, observations and documents analysis.

4 Findings

The four categories emerged from the interviews, informal discussion-type interviews, observations and document analysis.

A. The use of columnar data flow diagrams simplified the overall assessment of the system, empowering the students' motivational and cognitive skills and minimizing memory overload.
B. Time and efforts in drawing, checking and reading columnar data flow diagrams were reduced in comparison to standard data flow diagrams, enhancing system design skills.
C. The application of inference trees improved detection and correction of reasoning errors, overcoming students' limited information processing capacity.
D. Inference tree diminished logical fallacies in written reports, improving vision and transferring logical skills to face-to-face environments.

Findings regarding students' and the facilitator's experience of CDFDs

The above mentioned classification of the findings, with corresponding records related to the students and the facilitator's experiences of CDFD are:

A. ***The use of columnar data flow diagrams simplified the overall assessment of the system empowering the students' motivational and cognitive skills and minimizing memory overload.***

The following comments regarding the use of CDFD were recorded during the focus group interview with students'. "*…The columnar style of data flow diagrams is easier to understand because you know exactly where to go... the logic of input, storage and output is easy to detect. …*

The facilitator made the following comments in the observational protocol: "*Students were guided in drawing CDFD through the following self-reflective questions:*

Who is the user? What information does the user need? What extraction process is necessary to produce the information? From which permanent storage(s) should the extraction process obtain data? Which collection process is necessary to get data into each permanent storage? What data are available for the collection? Who supplies the data?

Comments in observational protocols indicated that the use of columnar data flow diagrams and specific questions simplified the overall assessment of the system, as students expressed that"*…we can easily count the number of inflow arrows and the number of outflow arrows in the columnar form…"*

Observations also indicated that the use of columnar data flow diagrams empowered students motivationally and cognitively, as "*they were more attentive, intuitive, focused on tasks and reasoning, they were thinking reflectively, clearly applying and thinking at an appropriate level of complexity".*

B. ***Time and efforts in drawing, checking and reading columnar data flow diagrams were reduced in comparison to standard data flow diagrams, enhancing students' vision and system design skills***

Students expressed their opinions during the focus group interview explaining that "*…CDFD is clear …it is easy to access, read, link, check… it is a system flowchart ...one can draw all links on one piece of paper... standard data flow diagram is difficult to read..."*

The facilitator commented in the observational protocol that "*… students found omissions in a form of gaps in the pattern of flow with a little effort and time…but they were happy drawing columnar diagrams for a higher level design …".*

Furthermore, the comments in the observational protocol confirmed that: "*In drawing columnar diagrams, students simplified the complex design process into simple steps, which involved filling all seven columns. They could find and eliminate errors without being confused…in checking CDFDs, students detected gaps in the data flow from left to right, and flow errors looking in the direction of arrows. In reading CDFD, students' recognized the function of each component, whether it is a source of data, an inflow of data into the system or a process that collects inflowing data. When they were searching for errors they looked in the relevant column instead of searching the entire diagram….They often compared the number of information outflow arrows with the number of data inflow arrows*."

Findings regarding students' and the facilitator's experience of inference trees

Students' and the facilitator's experiences of inference trees have been described in the following paragraphs.

C. ***The application of inference trees improved detection and correction of reasoning errors, overcoming students' limited information processing capacity***

Students commented in the focus group interview *"...we have a problem understanding system requirements… now I can detect links in documents … I get tired reading too many ideas scattered across documents …now it is easier to correct errors with the [inference] tree… …it is time consuming to draw an inference tree, but only at the beginning… now I can think deeper…"*

One student added in the informal discussion-type interview*: "… now I know how to write … I know how to present ideas and connect them …in that way I can convince my team members that my arguments are justified… my conclusions make sense..."*

During the requirements analysis phase students commented that their memory was overloaded by many facts and that they could not detect links"*…communication of requirements across stages was a difficult task… too many details and errors …I forget easily what happened earlier …"*

Furthermore, comments in the observational protocol revealed that students found irrelevant errors such as "*…they examined all inference outputs, and asked questions thinking loudly, whether outputs* *are true if the inputs are true... They searched for errors and in that way they missed the point, they did it because premises and intermediates didn't imply the stated conclusion, but instead implied a completely different conclusion*".

Observational notes further revealed: *"Students tried to detect reasoning errors in the inferences that link the core ideas of the various paragraphs simply by reading the report….They were lost, frustrated and simply left the task of detecting and correcting errors. Perhaps their memory was overloaded …through practice they learnt how to outline an argument using inference trees…"*

It was impossible in the allocated time frame to train students' how to detect different types of reasoning errors.

The analysis of documentation and reports indicated a clear argument construction, one core idea in a paragraph, connections of core ideas across paragraphs and clear conclusions. Using the words 'so, therefore, thus' was regular and justified in the text.

D. ***Inference tree diminished logical fallacies in written reports improving vision and transferring logical skills to face-to-face environments.***

During the interview students reported on improved vision and easier detections of logical links and elements in a system "*…I don't need to remember many details…I can see the whole system…"*.
The facilitator commented: …" *Most students have seen the benefits of using the inference tree because they reported on improved vision of the whole system… They noted detailed relations between components..."*.

Further comments indicated that "*…Discussions and brainstorming sessions were true reflections of the students' logical processes. When/In examples where they detected and corrected errors in documents/reports, the correct logical transfer was evident in discussions. For example the use of words, so, thus, therefore ..*:"

Evidence shows that the use of the inference tree helped the facilitator in teaching system analysis tasks. The transfer of logical skills from written to face-to-face communication was also evident in a form of expressing logical links correctly, i.e, using words 'so, thus, therefore'.

5 Discussion of findings

Findings indicate that the columnar tool helped the students to save the time in reading, drawing and checking a system flowchart (Hahn & Kim ,1999:183: cited by Mende & Mohamed, 1999). While students were drawing a system flow chart they could gain many advantages by arranging the symbols in seven columns according to their function. This structured approach in systems design made a data flow diagram easier to draw, check and read (Mende & Mohamed, 1999).

This was possible as the conceptual rationale (Mende, 1999) provided a basis for the use of the columnar method in the project-based classroom. In addition, the IWDP with its structure and an organized instruction based on learning theories and instructional strategies supported the application of CDFD as a logical tool (Jakovljević, 2002). Therefore, the columnar method provided a sound basis for the facilitation of students' systems design skills.

The CDFD seemed to assist students with a clear picture of the intended information system, following the rules of data flow diagramming (Whitten & Bentley,1998). Findings indicated that students visually assessed the *power* of the system by comparing the number of data inflows with the information outflows. In this way they were motivated to continue with the system design as the memory overload was minimized releasing their cognitive power.

Therefore, did the columnar method facilitate visual, motivational and cognitive skills providing simplified overall assessment of the information system (*as an answer to research question one*).

If designers drew an inference tree at the preliminary outline-design stage of report it would be of great use later on, as they would not waste valuable time correcting far-reaching reasoning errors (Mende, 2006). According to the findings, while students tried to detect reasoning errors in the inferences that link the core ideas of the various paragraphs simply by reading the reports or documents they were prevented due to human limited information processing capacities.

The findings indicate that instructing students how to use a variety of inference trees during system analysis helped them to detect, correct and even prevent logical errors. While students were exposed to different types of logical errors, they were able, through a variety of inference trees in a written form, to apply those skills in a face-to-face communication environment, for instance in discussion groups, release meetings etc *(as an answer to research question two*).

Observations indicated time constraints and there was evidence that students experienced drawing CDFD and inference trees as a cognitive strain. Perhaps, there was a need for a sustained practice in a undetermined time frame.

The CDFD and inference trees help to expand the student's self-regulation system (Bedny, & Seglin, 1999) as it provides self-structured feedback and a projection system not depending on the external human intervention. Therefore, these logical tools empower students' logical thinking expanding their self-regulation system.

Clarity (easy readability) in representing an information system, and providing an overview of logical links of an intended information system were major attributes of these tools as indicated in observational notes and systems reports/documents.

Mende, (2000, 2005, 2006) constructed a clear conceptual rationale and suggested that the columnar and inference trees should be applied in a wide variety of real-life contexts. Many investigations are still necessary to prove its value. Findings show that these tools could be applicable in a project-based classroom.

Thus, these logical tools can help students in acquiring a variety of analysis and design skills enhancing their memory, visual learning, logical thinking and vision (Boden, 1990) due to its simplified representational power. Skills of visualizing are necessary for learning technological processes (Fogarty & McTighe, 1993:163).

6 Conslusions

The following conclusions and implications for systems analysis and design contexts can be drawn from this inquiry:

- In the promotion and enhancement of students' system analysis and design skills, appropriate attention should be given to the relevant conceptual framework on the logical tools (CDFD and inference tree) and its application in a project-based classroom.

- Designing a systematic and innovative instruction within the IWDP framework supported with logical tools can help students to develop their conceptual and procedural knowledge (McCormick, 1997), through a set of pre-defined tasks and activities.

- Logical tools improve students' motivational and cognitive power and help them to create an overall picture of the information system and its components. Although logical tools support a structured approach in systems analysis and design, they resemble human information processing thus minimizing memory overload and increasing the quality of logical thinking. Therefore, motivational, cognitive and systems analysis skills can be improved. Furthermore, logical tools enhance students' arguments construction skills, providing a transfer of those skills into different learning environments.

- The CDFD may also be useful in object-oriented design, which tends to abandon these tools (Mende, 2000). So, when designers draw for example, use cases in object-oriented design, the columnar rules can be applied. Designing complex information systems with many use cases in a hierarchical form is confusing due to the nature of human limited information processing (Graham ,1994; Blaha M & Premerlani ,1998). Therefore, the inference tree helps to make logical conclusions during an object-oriented design, where misunderstanding of design diagrams is a common practice.

- The paper suggests that CDFD could provide an overview of the intended system, which fosters deep learning. Inference trees should be used during systems analysis tasks, particularly in writing reports/documents. The use of inference trees improves logical thinking of systems analysts and designers, and decreases errors in reasoning.

- Time constraints and some cognitive exertion in drawing diagrams were indicated in the findings. These issues should be carefully considered in order to successfully integrate logical tools into a project-based classroom. Thus, these aspects also present methodological limitations of this study.

This paper was an attempt to investigate the applicability of logical tools in an information systems analysis and design context. The advantage was also that these tools were applied in an organized manner with the support of the IWDP, in an innovative learning and instructional environment. The paper explains that these tools are better utilized if they are integrated within an instructional system, the Instructional Web Design Programme (IWDP).

Although a conceptual framework and research findings suggest that the logical tools should be widely applicable, there is a need to investigate the use of these tools in different IS environments, in order to provide conclusive evidence of wide applicability. There is a special need to determine the limitations of the logical tools by investigating their applications in different real-life IS analysis and design environments.

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