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Reducing Accident Causation in Complex Plants by Identifying Mutual Misconceptions Between Designers and Operators

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ABSTRACT

Catastrophic accidents in complex plants arise from an unforeseen combination of a number of factors. Although much effort has been invested in both improving the reliability of components, and the design of user interfaces, human error and complex plant failures still occur. One contributing factor to plant accidents is the nature of understanding that design engineers and operators have of each other, or rather the mutual misconceptions that arise between them. For example, operators may adopt practices that do not reflect the demands and limitations inherent within the design of a plant. Similarly, the design engineer may prescribe practices that cannot be successfully completed due to limitations inherent within operators.

This paper describes the development of a database that attempts to capture these mutual misconceptions. The database has been produced from causal analyses of case studies of previous accidents involving complex plants. In addition, the database forms the basis of the development of an agenda-generating mechanism for use by designers and other decision makers. The tool provides cues to key decision points and managerial activities that influence the design and operation of a plant. It lets the decision makers choose the level of abstraction at which they are cued by the agendas of misconception type. For example, in writing shut down instructions, it is important that the authors can see all the main types of operator misconception that are associated with shutdown activity, and that they can navigate to more detailed sub-types, or even specific accident accounts. The tool is designed to help decision makers avoid the types of mutual misconceptions that have been implicated in previous plant accidents, and hopefully increase their understanding of the demands they place upon operators.

Reducing Accident Causation In Complex Plants
By
Identifying Mutual Misconceptions Between Designers And Operators

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Abstract
Accidents in complex plants arise from unforeseen combinations of human, procedural and technological failures. Although considerable amount of effort has been invested in both improving the reliability of components and the design of user interfaces, accidents are still happening. A contributing factor to such plant accidents is the nature of the understanding the design engineers have about the operators and vice versa, or rather the mutual misconceptions that arise between them. This paper describes the development of a database that attempts to capture these mutual misconceptions. The database has been produced from causal analysis of previous accident descriptions involving complex plants. In addition, the database forms the basis of the development of an agenda-setting tool for use by designers, operators and other decision makers. The tool is designed to help them explore the types of mutual misconceptions that have been implicated in previous plant accidents, and hopefully avoid similar accidents in the future.

Keywords: Accident, Agenda, database, misconception, complex plant

1. Introduction
Complex, hazardous installations like offshore platforms are naturally vulnerable to designers designing in a way that impedes operators' reasonable intentions. They are equally vulnerable to operators misunderstanding reasonable intentions on the part of designers. For example, the design engineer may prescribe practices that cannot be successfully completed due to limitations inherent within operators, such as the limited capacity of working memory (Eysenck and Keane, 1995). Similarly, operators may adopt practices that do not reflect the demands and limitations inherent within the design of a plant.

The most fundamental bias in decision-making is the manner in which prior decisions are used to inform present decisions. Cherrington (1994) suggested that individuals would enact a search across a decision-space to identify decisions previously made for similar situations. It was suggested that when the individual locates a decision that led to an appropriate outcome in a prior situation that this would be applied to the present situation. Implicit within this is the view that the individual will not necessarily refine the decisions they make if a decision that provides a satisfactory outcome already exists. Consequently, unless designers and operators are explicitly taught to think about the misconceptions, these will never form part of their decision-making processes.

However, if the individual seeks to identify the mutual misconceptions that occur, then feedback about failures within complex plant must be available, timely and attended to. Feedback that is presented some time after an activity has been completed is of little use if the decision-making process that led to that activity has been forgotten (Wickens and Holland, 2000). Further, the presence of hindsight bias, the belief that the factors that caused the accident could have been identified beforehand, may lead the individual to believe that there is nothing to be learned from the accident (Fischoff, 1977). Consequently, unless the individual is provided with information about the forms of mutual misconception that occurred, then they may not be able to spontaneously identify these from feedback about the complex plant's operation.

Further the individuals need to maintain their own self-esteem may lead them to dismiss the problems that befall others and to suggest personal characteristics in the individual that led to the accident (Burger, 1981; Heider, 1958). This is potentially a problem for both operators and designers, where the characteristics of the complex system that made the accident inevitable are ignored. Again, there is a need to ensure that the individual is provided with the misconceptions that are made by the group to which they belong, either operators or designers.

The purpose of this work is to provide designers and operators with knowledge of the mutual misconceptions that can occur between them and to encourage them to reflect on the mutual misconceptions that can arise between them. For designers this involves recognising the role that their designs can play in accident causation, and for operators the role their assumptions about the system play. This is achieved in two steps:

1) identify and classify mutual misconceptions by conducting causal analysis of past accidents reports;
2) create a framework and computer tool based on the mutual conceptions to provide cues to operators and designer for identifying potential hazards.

Section 2 provides a brief description of the work carried out under step one. Sections 3 and 4 describe the outcome of step two. Section 5 gives a summary and outlines the future work.

2. Mutual Misconception Database

In this paper, the term *misconception* refers to the possession of an incorrect or inappropriate belief or assumption by an individual about some aspect of the complex system. This includes those who design or operate the system, the environment in which the system operates, the processes and activities conducted with it, and the properties of materials. An example of an operator's misconception about a design is that he may believe it performs a particular function that it does not. An example of a designer's misconception about an operator is that he may believe that the operator will not misinterpret a particular display. The term "operator" is used very loosely here to refer to all personnel involved in the operation of a complex system, such as maintenance engineers, supervisors, managers etc.

Causal analysis was carried out to identify misconceptions in over 100 past accident records (Busby et al, 2001). The records analysed are from a number of sources including the Marine Accident Investigation Board's Safety Digest and two books (Crowl and Louvar, 1990; Kletz, 1998).

The analysis procedure requires the identification of a specific outcome and its immediate cause. Following from this it may be possible to further identify subsidiary causes that contributed to the immediate cause. The identification of subsidiary causes continues until the root causes present within the case-history are identified, which may constitute either active errors, actions committed by operators, or latent errors, causal factors arising from decisions taken during the design of a particular process plant. Once root causes have been identified it is then possible to consider the mutual misconceptions that may have contributed to this specific accident. Whilst identification of a root cause may provide a means to identify a specific inappropriate action from operators that the designer can avoid, the analysis of mutual misconceptions provides a means by which to understand why both designers and operators failed to consider the presence or consequences of specific actions.

The analysis resulted in a Mutual Misconception Database that links the descriptions of accidents with their corresponding causal analysis and the misconception hierarchy (Das et al, 2001).

3. A Framework For Identifying Mutual Misconceptions

The mutual misconception database is a useful source of information. However, the information is not in a form that can be readily used by plant personnel for hazard identification purposes. There is a need to provide a framework and tool for operators and designers to identify, and communicate with each other, the misconceptions that they may possess.

It is known that when individuals identify appropriate sources of responsibility, consider causative models of certain complexity or attend to feedback, individuals may not necessarily assess all the relevant conditions when reaching a decision. To overcome this phenomenon referred to as biased reviewing (Reason, 1990), the framework must promote systematic reflection and discussion.

The main component of the framework consists of two lists of general misconceptions, one relates to misconceptions that designers may have and the other relates to operators. The lists are derived from, and cover all of, the identified misconceptions. The designers list is stated as expectations or non-expectations. The operators list is stated as assumptions. For example, the list of assumptions that operators sometimes make are:

- alarms which contradict other indicators can be ignored;
- all you need to know is contained in procedures;
- automated systems can be substituted by manual ones;
- everyday intuition is a good guide to hazards;
- if you test for X and the test is positive then X is true;
- mandatory rules err on the side of caution;
- the designer of the system is reasonable;
- the equipment you need to work on can be identified unambiguously;
- the past is a good guide to the future;
- the system and its safety devices work perfectly;
- there's only one indicator for every parameter;
- what's available is what's needed;
- when equipment stops you carrying out your task it's faulty;
- when the rationale for something is not obvious it doesn't matter;
- work or attention can be offloaded onto safety systems;
- you can concentrate completely on the task in hand when it gets tough;
- you can work out the function of an object from its form;

- you have the knowledge to take risk wisely.

The two lists are to be used as prompts by designers and operators to think through where in the design, or operation, of a plant these assumptions or expectations are held and whether these assumptions or expectations are valid.

Links between each item on a list and the relevant accident records from which it was derived are kept. The reason for maintaining the links is that the accident records can be used to illustrate how, in different situations, the same type of invalid assumption was made and ended up in accidents.

Basing the identification framework on past accidents has several advantages:

- it is more likely that operators' behaviour will be modified if the information provided to them comes from a credible source, such as a government report, or respected safety expert;
- the concrete information helps the users to see the relevance to their own behaviour (Nisbett and Ross, 1980);
- the vivid description of fatal incidents has the potential of promoting greater behavioural change (Triandis, 1971).

4. Description of the Agenda-setting Mechanism

In order to help plant personnel apply the identification framework in an efficient and effective manner, a computer support tool, called the Agenda-setting Mechanisms (ASM) package, was developed in Microsoft Access. The tool is so called because it is designed to help the user to select a list of items for consideration at key decision points during the design and operation stages of a plant. For example, during a design review prior to a HAZOP meeting or prior to making a plant modification.

The need for a formal intervention of this form should be apparent when consideration is given to the biases that emerge during decision-making. Designers and operators may gain ambiguous feedback that provides support to inappropriate outcomes of decision-making. Further, the absence of timely feedback may mean that the designer or operator cannot retrace the decision-making process that led to a particular decision and so cannot learn from it (Wickens and Holland, 2000). Further, the presence of hindsight bias and the need to maintain self-esteem may prevent the learner from identifying the need to learn from an accident, or to acknowledge the potential role of system components and operators in it, (Burger, 1981; Fischoff, 1977; Heider, 1958).

The ASM package attempts to remove this problem by allowing the user to see the consequences of particular decision-making processes as represented in the analyses of past accidents. Novel lessons about accident causation are presented to the learner, and the case provides support for this, in contrast to real-life situations where the opposite is true. Further, the identification of misconceptions allows operators and designers to acknowledge the role of interaction between them. Self-esteem can be maintained by acknowledging that both designers and operators have responsibility in the causation of accidents.

There are two further biases that can reduce the validity of the conclusions drawn from feedback arising from an accident. Firstly, the individual may hold an oversimplified view of causation, which will prevent them from identifying multiple root causes (Katz and Khan, 1978). Secondly, when the individual wishes to employ the findings gathered from the accident, they may be subject to biased reviewing, that is the individual will be unable to systematically consider all relevant components of the problem without prompting (Reason, 1990).

These problems can be reduced by the design of the ASM package. The causal analyses that have been conducted can demonstrate to the individual the complexity underlying the causation of accidents in complex systems. To alleviate the problem of biased reviewing a checklist can be used to ensure that the individual systematically works through every item on it.

The ASM package comprises a number of different elements to support the user in identifying the role of misconceptions in accident causation, by following the principles described. Figure 1 shows the Log-on window. It allows records to be maintained according to specific projects, and to amend information about that project at a later date. Selecting the *introduction* link can access various introductory materials about the program and how to use it.

To carry out a review, the user selects either the *designers* link or the *operators* link. Figure 2 and figure 3 show the windows for designer review and operator review respectively. When a user selects an item from the list of misconceptions a brief description for that misconception is provided. For example, figure 4 shows a description for the misconception "automated systems can be substituted by manual ones". Selecting the *cases* link on that window will show the details of the specific case(s) from which the misconception was identified (figure 5) and selecting the *worksheet* link will provide a form for entering details for the project whether the assumption was made and whether there were any reasons to support the assumption (figure 6). If the assumption is clearly justified then it is not a misconception, otherwise a misconception in the project is identified. A user, or team, can systematically work through the different misconceptions. When the *report* link is selected, the details from all of the worksheets are grouped together to produce a formatted report.

5. Summary and future work

Designer and operator misconceptions play an important role in accidents involving complex plants. Our research focused on identifying these misconceptions and making use of the information to create an identification framework to avoid future accidents. A computer support tool, the ASM package, that supports the application of that framework has been implemented and described.

Twenty companies have been asked to evaluate the ASM package, some of which are involved in the production of chemicals, others with the design and manufacture of equipment. Their views are sought regarding the ASM package's usability and relevance to how they currently conduct safety related reviews during the whole plant lifecycle. In addition, a detailed case study with one organisation is planned. This will show how the use of the ASM package affects decisions made by plant personnel, including those involved in both the operation and design of the plant.

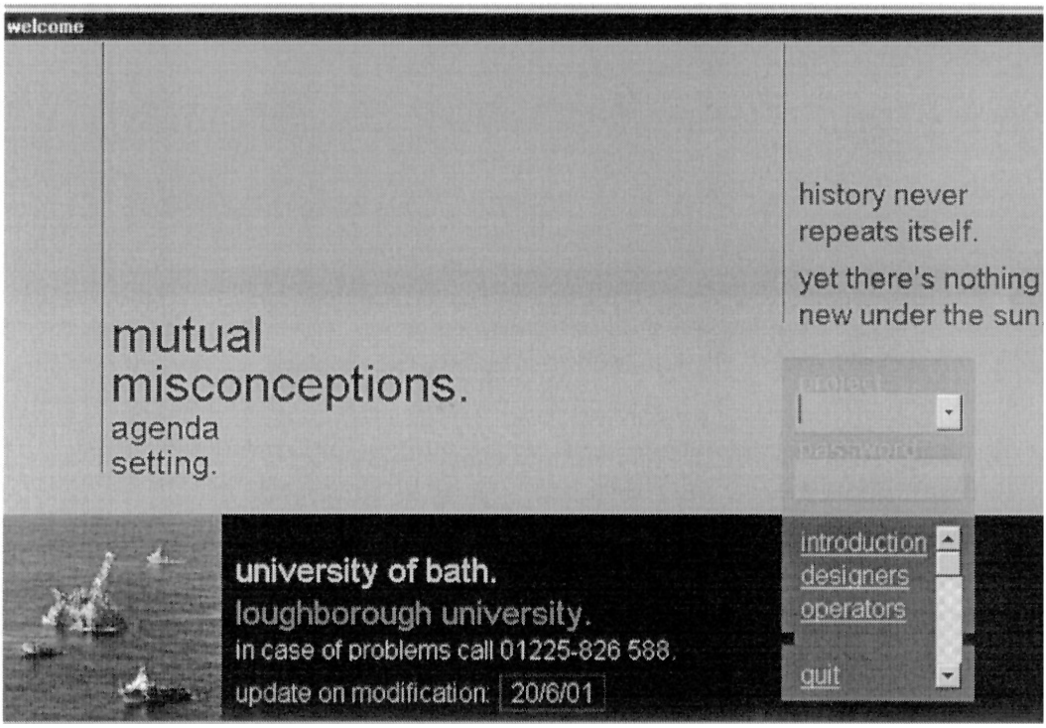

Figure 1 The log-on window

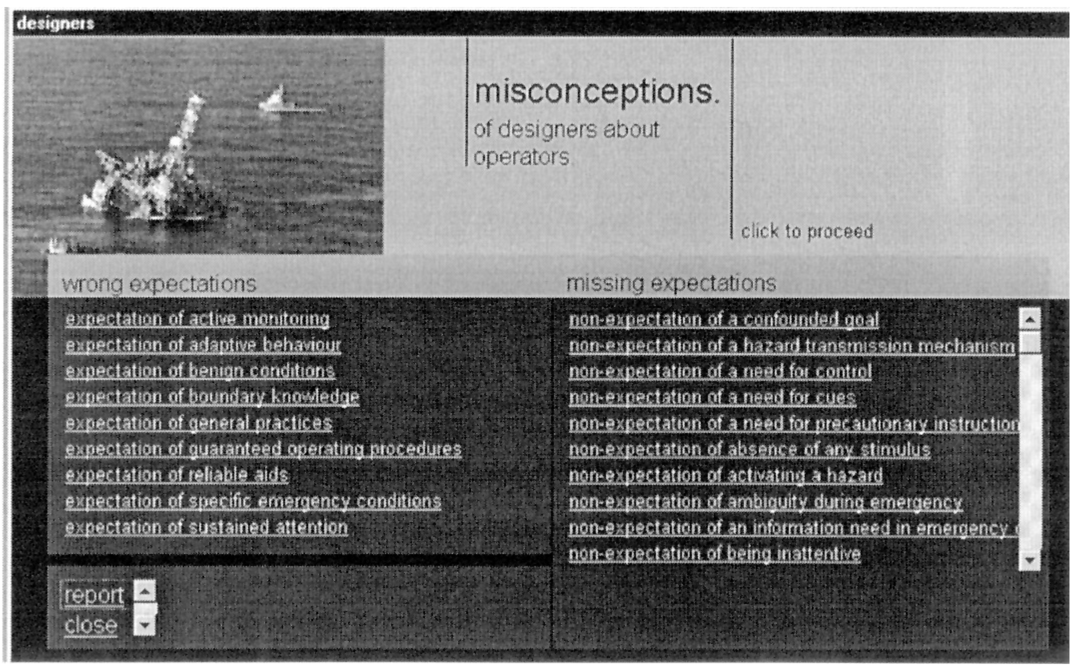

Figure 2 Misconceptions of designers about operators window

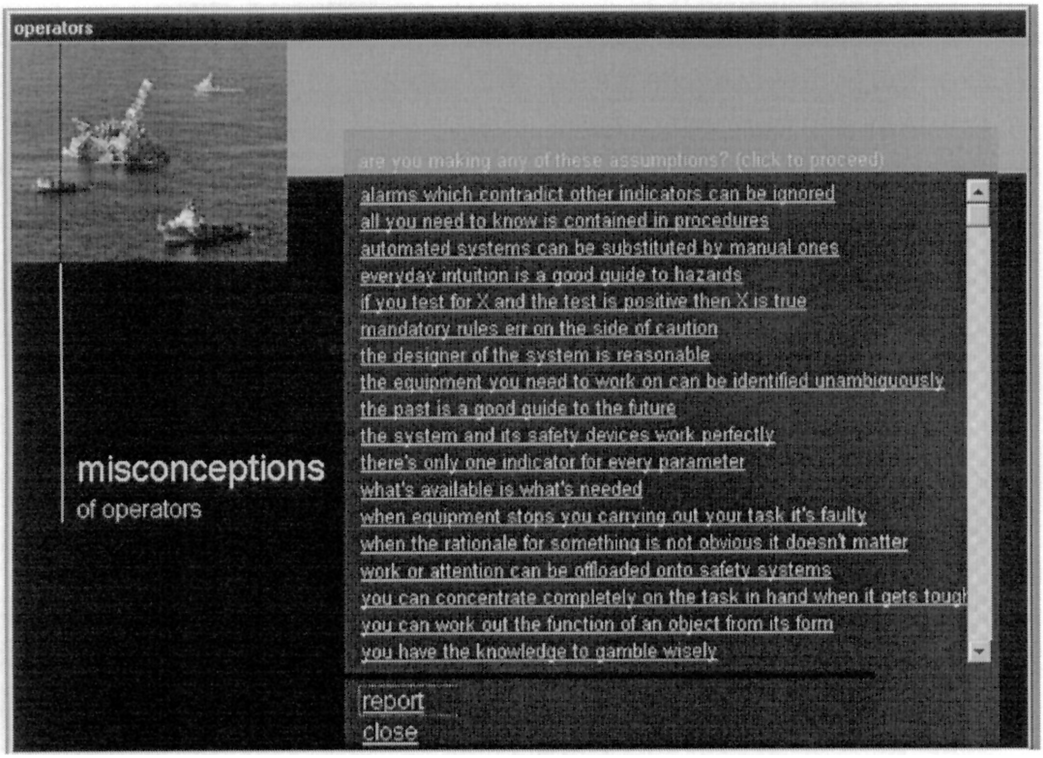

Figure 3 Misconceptions of operators window

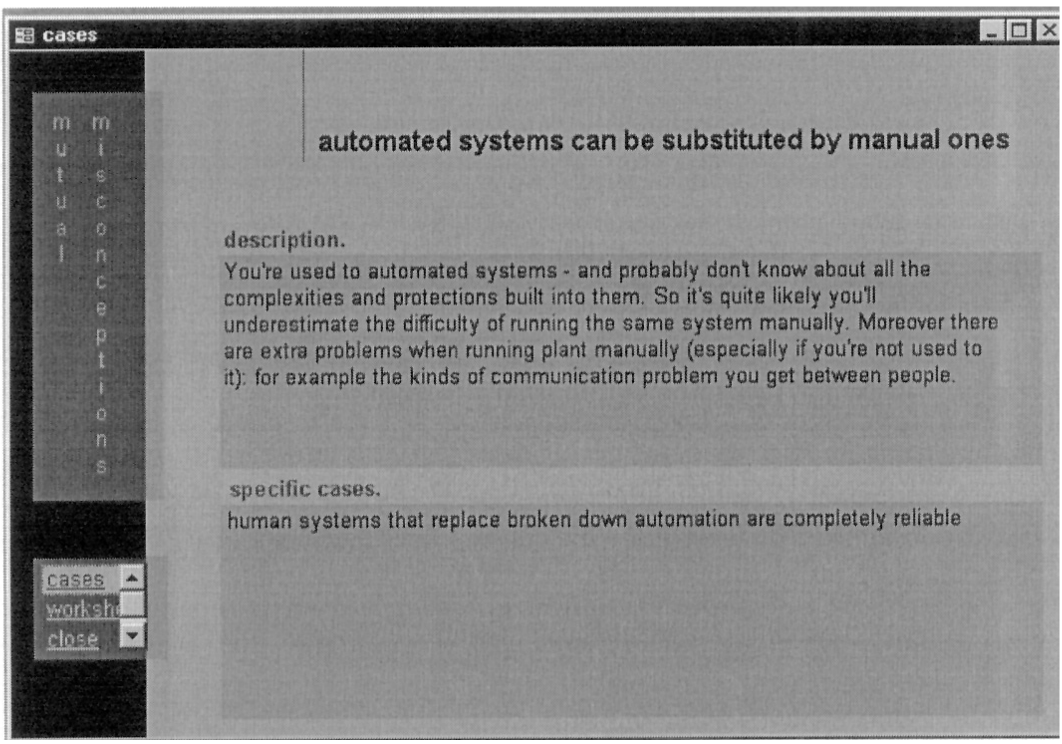

Figure 4 Window showing a brief description of a misconception

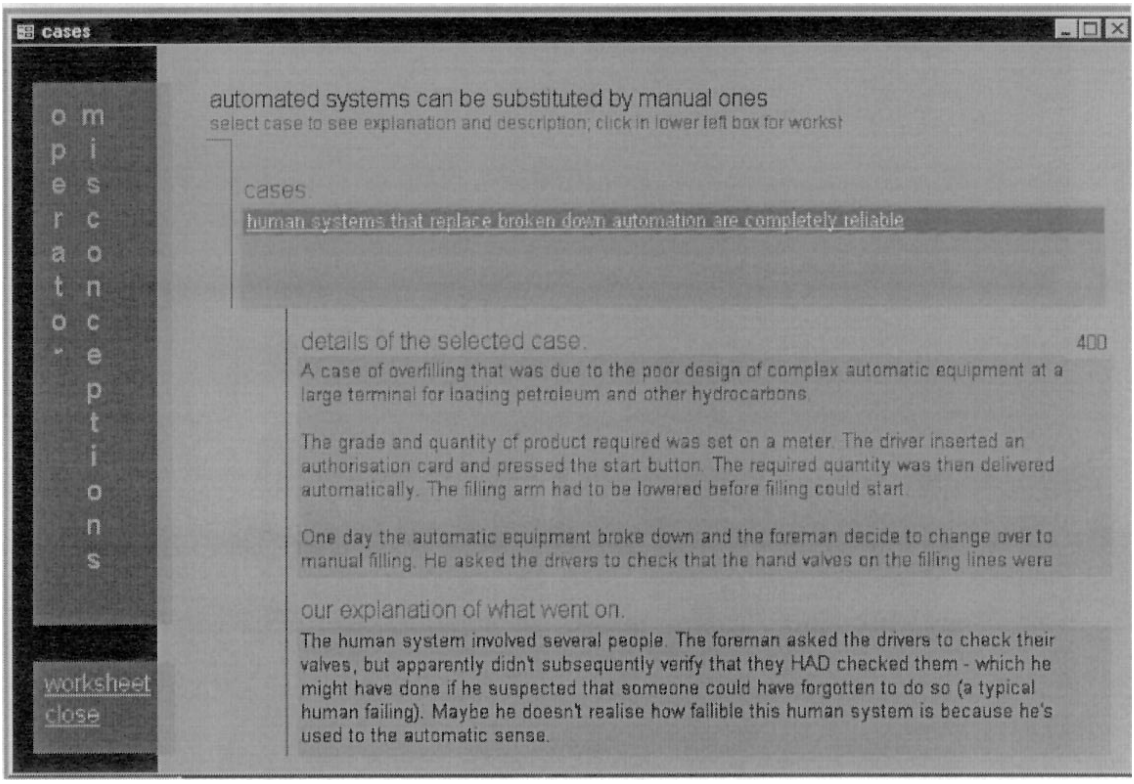

Figure 5 Window showing an accident description related to a misconception

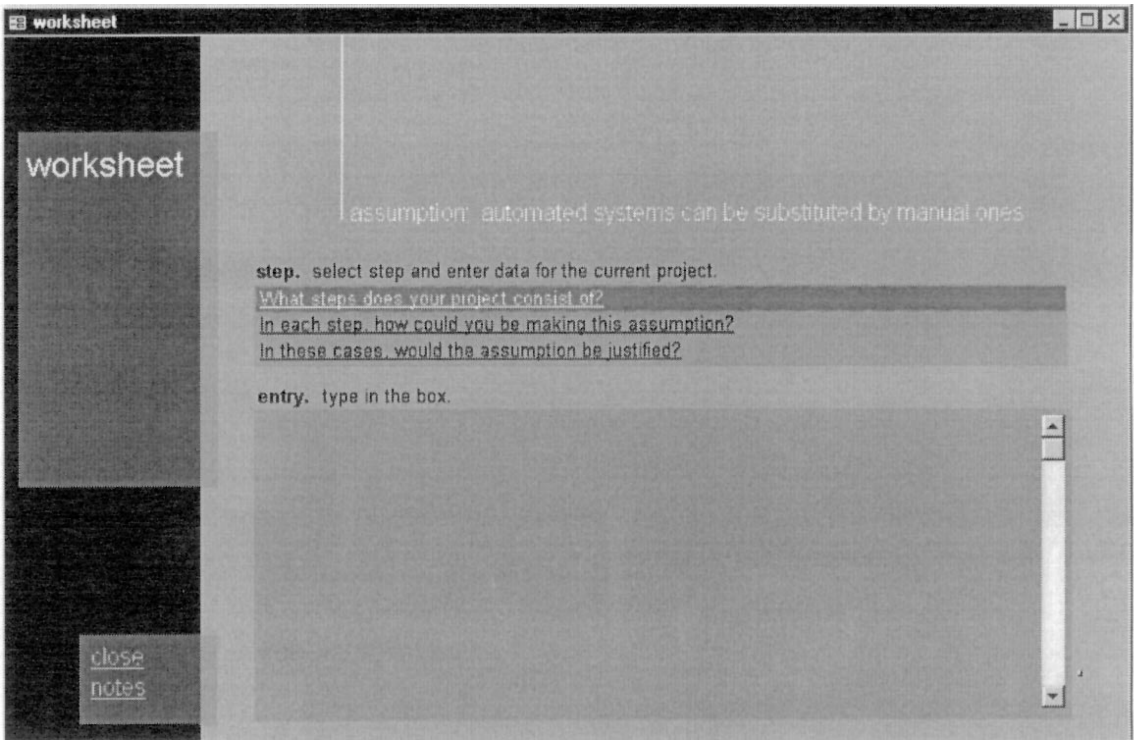

Figure 6 Worksheet window

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