A COMPUTER BASED PROBLEM SOLVING ENVIRONMENT IN CHEMISTRY

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ABSTRACT
The purpose of this study was to introduce the Mole Solver, a computer based system that facilitates monitors and improves the students' problems solving skills on mole concept. The system has three distinct modes that: i) finds step by step solutions to the word problems on the mole concept ii) enable students' to solve word problems on their own by using appropriate problem solving strategies iii) makes students aware of four step problem solving process.

INTRODUCTION

One of the goals of science education is to develop the learners' ability to acquire knowledge in specific subjects and to improve their problem solving skills. Problem solving requires overcoming all the impediments in reaching a goal. Many researchers showed that problem solving is one of the most important goals and a desired outcome of learning chemistry (Herron, 1996; Gabel and Bunce, 1994). Reid and Yang (2002) states that inappropriate chemical knowledge prevents students' problem solving ability in chemistry and students becomes unsuccessful if chemistry instruction does not provide them with an adequate set of rules to follow or do not help them to understand chemical knowledge during the learning process. Hence, it is essential to help students to understand the pre-requisite knowledge and skills of problem solving and avoid them just simply apply memorized skills in rote fashion.

Problem solving has been defined in variety of ways. Dewey (1938) stated that a problem is anything that gives rise to doubt and uncertainty. According to Wheatley (1984) problem solving is defined broadly as what one does when one does not know what to do. Problem solving requires the logical and creative thinking (Bybee and Sund, 1990). Gagne (1977) defined the problem solving as a thinking process by which the learner discovers a combination of previously learned rules that he can apply to solve a novel problem. Pizzini (1989) defined the problem solving as a method of learning as well as an outcome of learning. Many researchers indicates that the use of problem solving instructional models and techniques to teach science influences the problem solving skill of students. Problem solving skills are promoted by providing an rich environment in potential for exploration and by encouraging students to reflect on their actions (Hass and Parkay, 1993). Polya (1957) systematized the efficient PS process as four stages: understanding the problem, devising a plan, carrying out the plan and looking back.

Problem solving skills are specifically important in the quantitative problems of chemistry. Nakhleh (1993) and Silberman (1981) points out that high school and freshmen chemistry students find it difficult to solve quantitative chemistry problems. Many studies indicates the importance of mole concept because of its direct link to other quantitative problems in chemistry (Niaz, 1995; Staver and Lumpe, 1995). It has also been suggested that understanding of mole concept is fundamental to students' understanding of other chemical topics such as molecular mass, molar concentration, molar volume, pH and chemical equilibrium (Voska and Heikkinen, 2000).

Students have difficulties in understanding the mole concept in chemistry and in applying their knowledge during problem solving because of its abstract nature. These difficulties might stem from the learner's psychological development, mathematical anxiety, visual abilities and the instructional methods employed (Reid and Yang, 2002). Hence, it is necessary to develop new learning environments incorporating the instructional strategies to enhance the learning of abstract science concepts in order to develop learner's problem solving skills. In this study, The Mole Solver, a computer based problem solving system, will be introduced.

THE MOLE SOLVER

The Mole Solver(MS) is a computer based problem solving environment that facilitates, monitors and improves the students' problems solving skills on mole concept. MS was designed specifically for encouraging students to participate actively into the problem solving process and facilitate their problem solving skills in chemistry. It has a built-in expert system that could analyze the word problems on the mole concept. MS analyze the word problem and converts the problem definition into givens and unknowns. The problem analysis phase of MS is language dependent and could analyze only Turkish text for the time being since the system was primarily developed for Turkish audience. MS searches for some predefined keywords in the written text and it tries to convert them into (amount, type, unit) pairs. MS recognizes mole, gram, litre , avagadro number, molecule number as the input unit. The amount should be written as numbers. MS could recognize floating point numbers

such as 5.72 as well as avagadro numbers such as 3.21*10^21. One could enter any of the elements in the periodic table as the type. MS also supports **compounds**. MS could also distinguish the special properties of the elements from its knowledge base such as whether it is a gas or not. However, it may sometimes require to enter special words, such as gas, to define the problem correctly. MS then groups the founded pairs into givens and unknowns by its predefined rules. There is not any limit to the number of pairs to be defined in the problem. However, two or there pairs is generally enough to define most of the mole problems. Table 1 summarizes some pairs found for a few examples of Turkish word problems.

Table 1: Some Problem types MS could analyze properly

Problem Definition	**Givens**			**Unknowns**		
Text	**Amount**	**Unit**	**Type**	**Amount**	**Unit**	**Type**
14 gram Fe atomu kaç moldür	14	gr	Fe	?	mole	Fe
0.04 mol Ca atomu kaç gramdır	0.04	mole	Ca	?	gram	Ca
56 gram Cl kaç mol NaCl bileşiğinde vardır?	56	gr	Cl	?	mole	NaCl
NŞA 6.72 litre CH4 gazı kaç moldür?	6.72	lt	CH4	?	mol	CH4
0.3 mol O2 gazının yapısında kaç tane O atomu vardır?	0.3	mole	O2	?	Avagadro no	O

MS has also facilities to enter the mole problems directly as givens and unknowns in a language independently manner and gives opportunity to the user to correct the mistakes resulting from an improper analysis of the problem by the system. Data Input Window of Mole Solver includes three distinct places to enter amount, unit and type respectively (See Figure 1). The unknowns could be defined by entering a question mark in the amount. This window also has facilities to delete or change the properties of pairs and to check and analyze the problem definition itself.

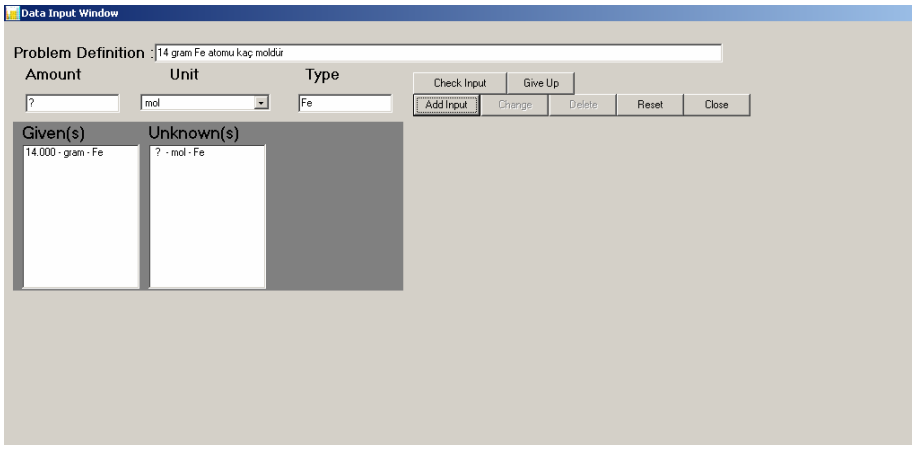

Figure 1: Data Input Window of Mole Solver

MS solves the entered problems with the help of its strategies. Table 2 summarizes the implemented strategies for the system.

Table 2: Problem Solving Strategies implemented in Mole Solver

Strategy Names	
Transfer from Gram to Mole	Find part from a Whole
Transfer from Mole to Gram	Find Whole from Part
Transfer from Mole to Litre	Transfer From Avagadro No to Mole
Transfer From Litre to Mole	Transfer from Molecule No to Mole
Transfer from Mole to Atom No	Transfer From Molecule No to Avagadro No
Transfer from Mole to Molecule No	Transfer from Avagadro No to Molecule No

Apart from the problem definition, MS works bilingually both in Turkish and English and could output its results in English as well since it produces its results generically from a pre-specified text. Table 3 gives examples of Turkish and English text to convert the result of the application of a strategy by the problem solving engine of

MS although there might be sometimes language dependent details. The %s parameters in the explanations are replaced by the appropriate values found by the system while producing the output.

Table 3: Explanatory texts for the transfer from Gram to Mole Strategy

Language	Explanation
English	Firstly Let us compute how many grams a mole of %s is:\n A mole of %s contains %s elements.\n Its value is:%s = %s gram.\n If a mole of %s is %s gram, then %s Mole of %s is x gram.\n Then we find: x= %s * %s and x=%s\n Hence %s Mole of %s is %s Gram.\n
Turkish	Öncelikle 1 Mol %s ifadesinin kaç gram olduğunu hesaplayalım:\n 1 Mol %s ifadesi içinde %s elementlerini barındırır.\n Bu ifadenin değeri toplam:%s = %s gramdır.\n 1 Mol %s %s gram ise,%s Mol %s x gramdır.\n x= %s * %s ise x=%s\n %s Mol %s %s Gramdır.\n

There are three different modes of operation for MS: auto solving mode, normal mode, and Polya problem solving mode.

Auto Solving Mode: In this mode, MS automatically converts the entered text into givens and unknowns and finds the solution itself if it could be deduced from the givens with the help of available strategies (See Figure 2). It applies all the applicable strategies exhaustively and then deletes the unnecessary strategies while producing the final output.

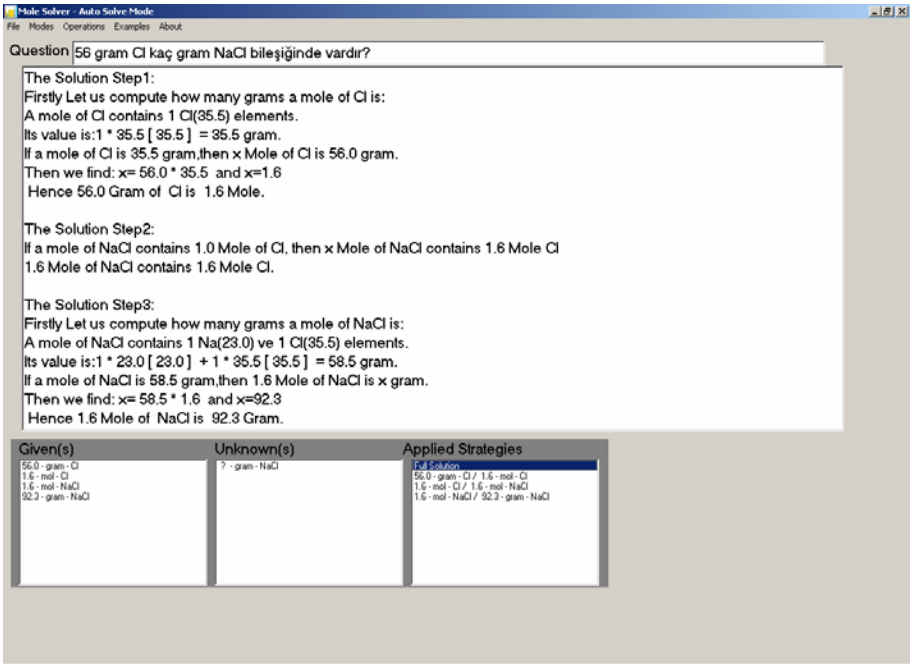

Figure 2: Auto Solve Mode of Mole Solver

Normal Mode: In this mode, users are required to enter themselves the problem by data input window. The users could ask the system to produce givens and unknowns or may modify the givens and unknowns pairs themselves. MS does not produce the solution automatically and requires users to select appropriate strategies to apply from the strategies menu (See Figure 3). One needs to select a given to apply a strategy and MS activates or deactivates the strategies with respect to the selected given. One could also apply strategies not directly related to the solution. These unnecessary strategies then could be removed by a related menu item remove unnecessary solution steps.

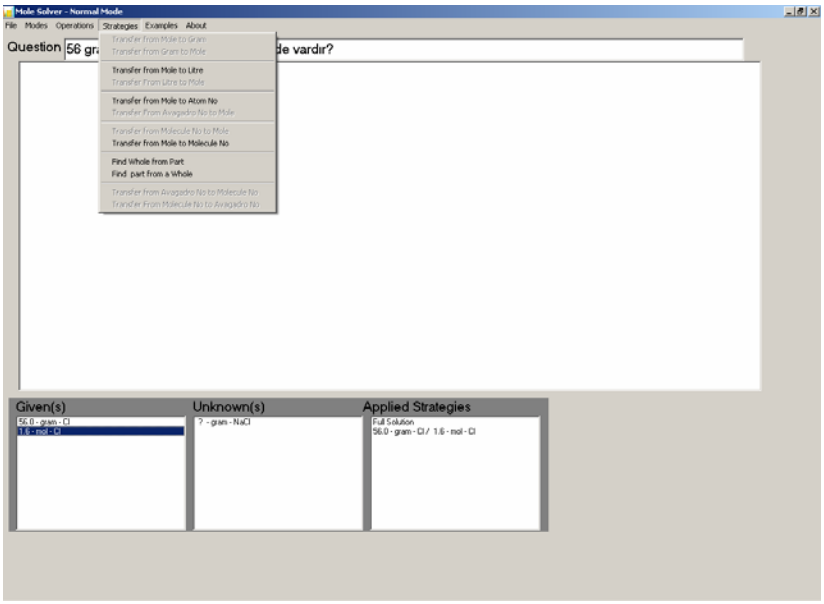

Figure 3: Normal Mode of Mole Solver

Polya Problem Solving Mode: In this mode, users are required to follow the four steps of Polya's problem solving method. Users are forced to complete each step: the step of understanding problem and entering data, the step of preparing a solution plan , the step of executing the plan and the step of revision of the solution. In the first step, they are required to enter givens and unknowns. In the second step, they are required to prepare a solution plan with the help of the strategies. In this step, the results of the execution of the strategies are not shown completely and numbers are replaced by letters to focus on the plan rather than the actual result (See Figure 4). In the third step, MS executes the selected strategy automatically for the user. In the fourth step, MS provides feedback to the user whether the solution is found or not.

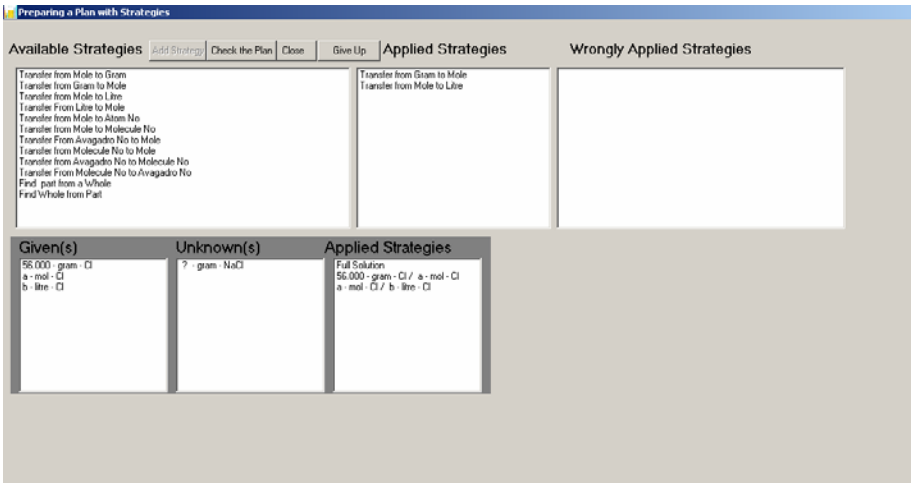

Figure 4: Preparing a Plan in the Polya Problem Solving Mode of Mole Solver

CONCLUSION

Mole Solver provides a flexible problem solving environment where users could develop their problem solving skills on mole concept. The problems on mole concept are usually algorithmic and MS gives user opportunities to try their strategies in its various modes. MS could analyze the problem for the user and may help them to understand problem definition and show the possible solution in the early stages of teaching of the subject.

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