DEVELOPMENT AND EVALUATION OF A SYSTEMIC ASSESSMENT FRAMEWORK IN ORGANIC CHEMISTRY

Chryssa Tzougraki, Katerina Salta, Theodoros Vachliotis
University of Athens, Department of Chemistry, Panepistimiopolis, Zografou, 15771, Athens, Greece
E-mail: tzougraki@chem.uoa.gr, ksalta@chem.uoa.gr, teovaxla@chem.uoa.gr

ABSTRACT

The Systemic Assessment Questions (SAQs) is an assessment scheme proposed in the Systemic Approach to Teaching and Learning (SATL) teaching model, aiming to a more effective evaluation of the systemic oriented objectives articulated by this model. The goal of a research project carried out in our department for the past five years is the development and evaluation of a systemic assessment framework based on SAQs for the high school organic chemistry. We initially focused on the potential of the SAQ scheme as well as its characteristics required to achieve in capturing aspects of students' meaningful understanding. It was found that SAQs' task format, diagrams' complexity, and cognitive demands play a significant role for this scheme in order to efficiently assess meaningful understanding of organic reactions. Based on these results, the SAQ scheme was then further developed and evaluated in various organic chemistry topics. Currently, a systemic assessment orientation was also adopted by focusing on systems thinking assessment. The SAQ scheme was found to be a valuable strategy for assessing meaningful understanding, as well as systems thinking in organic chemistry. A significant association was observed between students' performance on SAQs and on objective items designed for assessing meaningful understanding of organic chemistry concepts. This association indicates that the students' systems thinking level developed in organic chemistry is strongly related with a deeper understanding of the relevant science concepts. *[AJCE 4(2), Special Issue, May 2014]*

INTRODUCTION

The development of valid and reliable assessment tools is of a great concern to science education researchers. *Systemic Approach to Teaching and Learning (SATL)* is a teaching model that has been developed during the past decade [1-5]. SATL originators recognize as the basic goal of this approach the achievement of *meaningful understanding* by students and suggest that this goal can be attained through the development of *systems thinking*, in a context of constructivist and systemic oriented learning tasks (SATL techniques) [1-3, 5]. In this direction, they have proposed new types of assessment questions, the *Systemic Assessment Questions (SAQs)*, aiming to a more effective evaluation of the systemic oriented objectives in the SATL model [6-7]. The SAQs are concept mapping techniques approaching assessment in a systemic manner. Their construction is based on the idea that students could be facilitated to understand meaningfully if science concepts were viewed as closed, cyclic, interacting, and evolving systems, as meaningful dynamic wholes.

Meaningful understanding is a complex phenomenon. It goes beyond simple retention and recall of knowledge, i.e., rote memorization of facts and algorithms. It includes a variety of abilities, from creating links between different pieces of information up to explaining everyday life phenomena based on the current scientific knowledge. Accordingly, meaningful understanding is comprised of different types of knowledge and the ability to link these knowledge types [8]. Meaningful understanding of chemistry concepts includes the ability to link related chemical information resulting in making judgments, creating relationships, drawing conclusions, predicting what should happen. Meaningful understanding also includes the abilities to draw chemical information from a chemical representation and to construct a chemical representation using chemical information.

Systemics is a broad term, which takes into account the fact that there is a range of different systems approaches. Most of them offer a theory, a methodology for dealing with systemic issues or problems, and a way of thinking as well, namely systems thinking [9.]. Cabrera et al. [10] identify four rules or patterns of thinking that characterize all systems approaches, each of which is a special kind of relation between two elements: (a) *Distinction (identity/other):* draw distinctions between what is internal and what is external to the boundaries of the concept or system of concepts, (b) *relationship (cause/effect):* inter-linking one concept to another by identifying reciprocal causes and effects, (c) *system (part/whole):* organize parts and wholes into alternative nested systems, and (d) *perspective (subject/object):* reorienting a system of concepts by determining the focal point from which observation occurs, by attributing to a point in the system a view of the other objects in the system. According to the Distinction-System-Relationship-Perspective (DSRP) model, to become a systems thinker, one needs only to understand these four conceptual patterns and apply them in the context of a formalistic approach for systems thinking [11].

The SAQs is a novel assessment scheme which incorporates a concept map representation which is called a “systemic diagram” and represents a conceptual system having a closed, cyclic form. In systemic diagrams all concepts are interrelated, directly or indirectly, creating a closed conceptual structure which emphasizes the interactions between concepts. In the SAQ scheme, the valid analysis, construction, or completion of a novel systemic diagram with unique characteristics is required from the examinees. For accomplishing these tasks, students should be able to think in a systemic manner having developed important thinking skills, like the abilities of making distinctions, taking multiple perspectives, and creating relationships in order to organize a conceptual system, namely, to analyze the system to its fundamental components (concepts and links) and to synthesize these components into interconnected subsystems constituting a coherent whole.

The goal of a research project carried out in our department for the past five years was the development and evaluation of a systemic assessment framework based on SAQs for the high school organic chemistry. The project has been carried out in two phases. Initially, the focus was on the potential of the SAQ scheme as well as its characteristics required to achieve in capturing aspects of students' meaningful understanding [12]. Based on the results of this study, the SAQ scheme was then further developed and evaluated in various organic chemistry topics. A systemic assessment approach was also adopted by focusing on systems thinking assessment [13]. The methods used and the results of the project are outlined herein.

THE RESEARCH PROJECT

The First Research Phase

In this study, we preliminarily investigated if specific SAQs' forms are potentially valid and reliable tools for assessing 11th grade high school students' meaningful understanding of organic reactions.

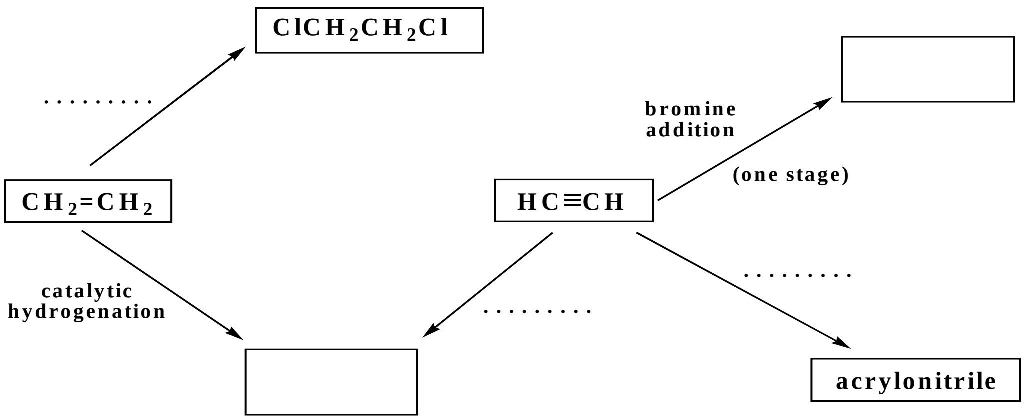
Methodology

We evaluated only the type of SAQs requiring the completion of semi-completed and structured systemic diagrams ("fill-in-the blanks" SAQs) with missing components not provided [12]. This type of SAQs has a constrained task format and we selected it considering that it is more consistent with the conventional objective questions often used for assessment in high school, and thus more familiar to the students. We had to determine the characteristics of SAQs under study. Firstly, we had to select the number of concepts in SAQs' systemic diagrams. There is no logical constraint on the number of concepts in these diagrams. Thus, we decided to comparatively evaluate two SAQs including systemic diagrams with quite a different number of concepts: the first SAQ consisting of six concepts, and the second SAQ consisting of eleven concepts. For this purpose, and given that data collection would be subsumed under the formal Greek high school two-semester assessment, we were oriented towards the construction of two tests (A1 and B1) each containing one of the two compared SAQs, along with some conventional items. These items, requiring just recall of knowledge, would allow us to collect evidence for the "meaningful-rote" character of SAQs under study.

Secondly, we had to select the amount of what would be provided to and what would be required from the examinees. Once again, we selected different amounts of provided features and requirements for each of the two SAQs, with the second SAQ being more demanding for the examinees. Moreover, the second SAQ was constructed to be more "less-directed" compared with the first one. Our next concern was to establish a clear scoring method for SAQs' items. In a SAQ's systemic diagram, the various components of the diagram are all interrelated, directly or indirectly, constructing a meaningful whole, i.e. an interconnected conceptual system, with a non-hierarchical structure. We consider that each of these components equally contributes to the creation of this conceptual whole. Therefore, we suggested a 1 point score for each valid component filled-in. The SAQ, as well as one of the conventional questions (CQs), from each of the two tests, A1 and B1, are presented in Figures 1 and 2, respectively.

1) In the following diagram:

a. Fill-in the blank squares with the chemical formulas of the proper compounds.
b. Fill-in the blanks on the arrows with the names/types of the reactions.
c. Two more chemical reactions can be filled-in between compounds in the diagram. Draw the arrows corresponding to these two reactions and complete on the arrows the names/types of the reactions.



2) Fill-in the blanks in the following propositions:

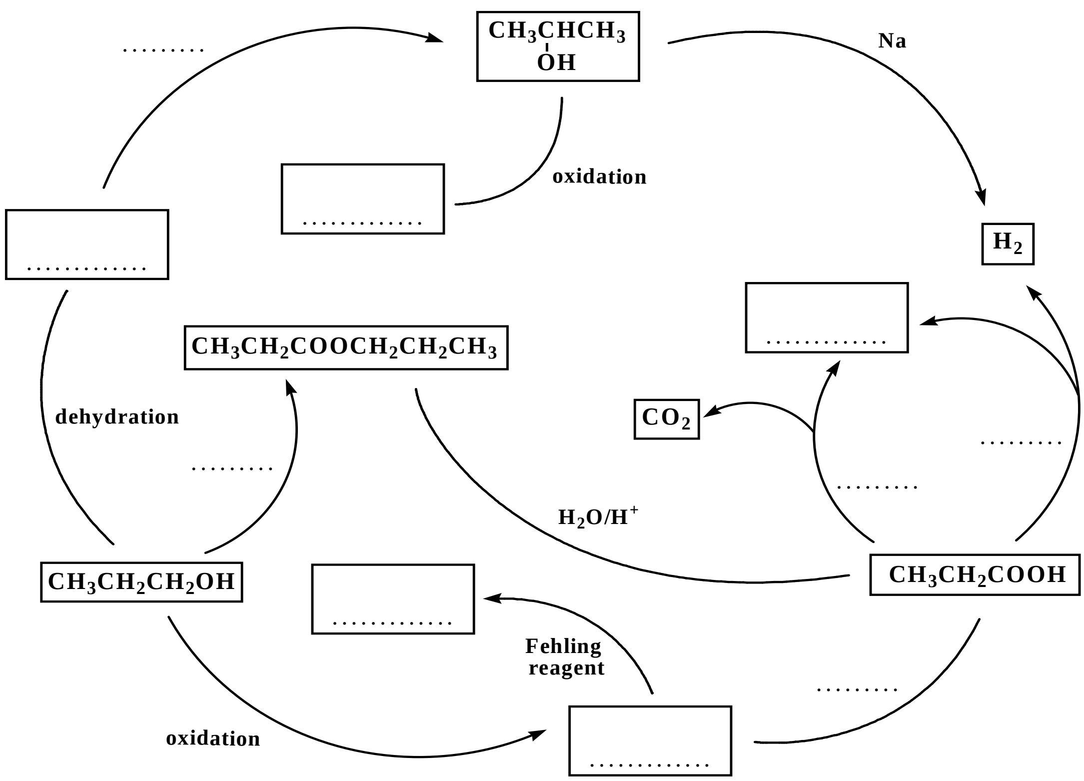
a. By the addition of water in acetylene in the presence of $H_2SO_4/HgSO_4$, the final stable product is …………………… .

b. ……………………… is the product from the trimerism of acetylene.

Figure 1: Two questions (SAQ and CQ) included in the test A1.

1) In the following diagram:

a. Define the direction of the undirected linking lines (4 lines).
b. Fill-in the 5 blank squares with the chemical formulas of the proper compounds.
c. Fill-in the 5 blanks on the arrows with the reagents/conditions of the reactions.
d. Fill-in two more chemical reactions between compounds in the diagram (draw the two arrows corresponding to these reactions and complete on the arrows the names/types of the reactions).



2) Choose the right answer for each of the following propositions:

a. It shows acid character:
i. ethanal ii. 1-propanol iii. butanone iv. propanone

b. It can be detected with addition of a carbonate salt:
i. 2-butanol ii. butanal iii. butanoic acid iv. ethanol

Figure 2: Two questions (SAQ and CQ) included in the test B1.

Although conventional questions were purposefully constructed to be closer to the "rote" edge of the learning continuum, we were also interested in observing the influence of some other variables on their "meaningful-rote" character. One of these variables was the "sequential" form of organic reactions. Our experience in teaching high school organic chemistry, as well as literature report [14] suggest that students are often incapable of relating individual reactions in sequential reaction schemes. Therefore, we included in the tests some conventional questions having a “sequential reaction” format. Furthermore, some of the employed conventional questions included organic compounds which were not exactly the same with those presented in the textbook. This variable is related with transfer of knowledge and was expected to enhance, more or less, the questions’ “meaningful” character.

Seventy-two 11th grade students from a public suburban high school in the Athens area participated in this study. The study was conducted over a five months period and in two stages: In the first stage, the chemistry of hydrocarbons was taught. One chemistry teacher carried out the course using the traditional approach (lectures including presentations and discussions) in 10 teaching hours. Students were provided with worksheets including various types of conventional objective questions as well as some linear questions. The latter had a similar format with SAQs, but different diagrams’ forms including concepts in a linear arrangement. These linear questions were used in order the students to become familiar with the symbolic representation of organic reactions used in SAQs. Afterwards, students were provided with worksheets including some authentic SAQs. At the end of this stage the test A1 was administered. In the second stage, the chemistry of alcohols and carboxylic acids were taught. The course was carried out in 12 teaching hours by the same chemistry teacher, using two series of systemic diagrams corresponding to the two topics under study. Based on the preliminary diagram from each series, the students, guided and supported by their teacher, using a step-by-step approach constructed the final full diagram for each topic. In addition, students were provided with worksheets including various SAQs’ formats and some conventional questions. The last step of this stage was the administration of the test B1.

Results from the first research phase and discussion

The evidence of items' validity was calculated with "item-total score" correlations using the Pearson's correlation coefficient (r) and the results indicated that all items contribute to the validity of the tests. The reliability for each test was calculated by Cronbach's alpha, which was found 0.76 for the first test and 0.83 for the second test, showing that the scales have an acceptable reliability.

The hypothesis of the two dimensions ("meaningful" - "rote") was tested using exploratory factor analysis. For both tests (A1 and B1) the appropriateness of the factor model was indicated by the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy. Principal component analysis using Kaiser's criterion [15] and scree-plot resulted in two common factors, which were subjected to a varimax rotation. A minimum factor-loading criterion of 0.40 was adopted for the final interpretation of the results [16]. Taking under consideration the items' content and requirements, the more reasonable explanation is that the one principal factor is the "rote" factor, while the other is the "meaningful" one. For the test A1, the fact that two of the three items of the SAQ-A1 (1a and 1b, Figure 1) were strongly loaded on the "rote" factor indicates that the characteristics of this SAQ are not suitable for assessing meaningful learning. For the test B1, all the items of the SAQ-B1 (Figure 2) were strongly to moderately loaded on the "meaningful" factor. This result indicates that the characteristics of the SAQ-B1 are more suitable for assessing meaningful learning compared to the SAQ-A1. A logic conclusion is that, the more "less-directed" SAQ including a more complex systemic diagram and with higher demands from the examinees, was found to be more appropriate for capturing students' meaningful understanding of organic reactions. Regarding CQs in both tests, most of them were strongly loaded on "rote" factor as was expected. However, the items having a "sequential reaction" format or requiring a degree of knowledge transfer showed a relatively increased "meaningful" character.

This investigation indicated that SAQs under study have acceptable psychometric properties and are suitable to be used as assessment tools in high school. Exploratory factor analysis revealed that the characteristics of SAQs seem to play a significant role as for their effectiveness for assessing meaningful learning. Between the two compared "fill-in-the blanks" SAQs, the more "less-directed" and demanding which incorporates a more complex systemic diagram was found to be more suitable for this purpose. Concerning the conventional questions, constructed to assess simple recall of knowledge, their "sequential reactions" format as well as the incorporation of "not included in the textbook" compounds seem to enhance their "meaningful" character.

The Second Research Phase

In this phase, the SAQ scheme was investigated as a strategy for capturing students' systems thinking skills in organic chemistry. Various types of objective questions were also developed and evaluated for assessing meaningful understanding. Moreover, the relationship between students' responses on the applied assessment schemes was explored.

Methodology

Two achievement tests, the test A2 and the test B2, were designed for the purposes of the current study. The test A2 assessed students' knowledge about basic organic chemistry topics, such as the classification of organic compounds, the IUPAC nomenclature for aliphatic compounds, and the constitutional isomerism of organic compounds. The test B2 assessed students' knowledge about aliphatic hydrocarbons, with an emphasis on their chemistry. Both tests were constituted by two assessment schemes: the objective items and the SAQ items. The tests were subsumed under the formal high school summative assessment.

To develop a coherent systems thinking assessment tool, we used the assessment triangle framework articulated in Pellegrino, et al [17]. According to this framework, there are three key elements underlying any assessment: a model of student *cognition* and learning, a set of beliefs about the kinds of *observations* that will provide the evidence of students' competencies, and an *interpretation* process for making sense of the evidence. Trying to articulate the systems thinking construct, we focused on Cabrera's et al [10] approach. Systems-thinking seems to be inherently related with the ability to analyze a system to its fundamental components/subsystems and to synthesize these components into a meaningful whole, namely, to organize a system of interest. According to the DSRP model, these tasks are accomplished by repeatedly making distinctions between systems' components, taking multiple perspectives within the system, and identifying the relationships between the parts of the system.

On this basis, we conceptualize the systems thinking construct as a three-step cognitive procedure, characterized by the repeated, step-by-step, implementation of the DSRP processing rules [13]. In a first step, some individual and conceptually unrelated concepts and/or links are identified within the defined conceptual system. In a second step, two or more components are recognized which are connected with a particular relationship, formulating a larger conceptual subsystem that is a part of the whole system. In a final step, all the interconnected larger parts/subsystems constituting a meaningful whole are recognized.

Fill-in-the blank SAQ items were designed to tap high school students' systems thinking and were included in both tests. SAQs' characteristics were selected based on the results of the first research phase. Both SAQs had a similar format and characteristics. However, the content of the test-B2 SAQ concerns chemical equations, namely, a specific symbolic representation of organic reactions. In contrast, the content of the test-A2 SAQ is more linguistic requiring less representational competence from students. This difference between SAQs could reveal some preliminary evidence regarding the potential of a more general and extensive use of the proposed systems thinking assessment framework, regardless of the topic or the subject matter to be assessed. The two SAQs developed in the second research phase are presented in Figures 3 & 4.

To successfully complete the SAQ diagrams, a three-step identification procedure should be carried out. By implementing analysis and synthesis procedures, students should first identify the engaged concepts and links, i.e., the fundamental components of the conceptual system of interest. If some of these components are connected with a particular relationship (interrelated), then the corresponding conceptual subsystem, which is part of the whole system, will have been identified. The most desirable outcome will be the recognition of all the interconnected subsystems, namely, the identification of the whole system under study. In each of these identification steps, students should repeatedly implement all the DSRP rules. The items were pilot tested with a small group of students for overall clarity, accessibility, and compatibility with the teaching content.

In the following diagram: **(a)** Fill in the blanks in eight squares, **(b)** Fill in the six blanks on the arrows with the proper words or phrases, **(c)** Define the direction of the five undirected linking lines, **(d)** Fill in two more relationships (draw two arrows corresponding to those relationships and label the arrows with the proper words or phrases).

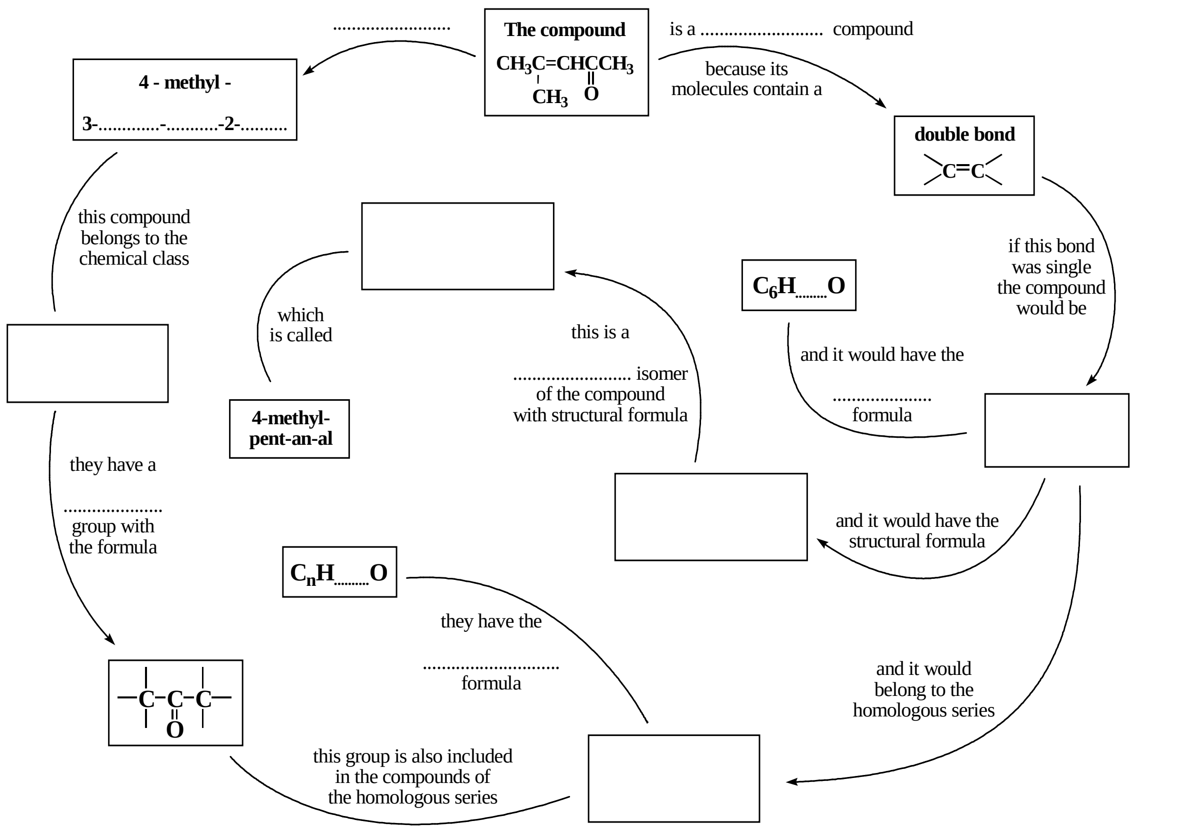


Figure 3: The SAQ included in the test A2.

Based on the above mentioned conceptualization, we consider the systems thinking construct as a cognitive procedure that progressively distinguishes three identification steps which include five levels of skills in total, from the "no-connection" level (scored as 1) to system level (scored as 5). The levels "partial connection" (scored as 2), "full connection" level (scored as 3), and "complex connection" (scored as 4) depict the identification of unrelated concepts and links, of one subsystem, and of two or more subsystems respectively [12]. A more practical "one point for each correct component filled-in" scoring scheme, which is more accessible to a teacher in the context of a classroom assessment, was also used for SAQs. The correlation between the two scoring schemes was examined.

Regarding the objective item scheme, the items should provide opportunities for students to link chemistry information and to translate and construct chemical representations. Advantages of different type items (fill-in-the blank, multiple choice, true-false, and matching questions) are utilized. All the fill-in-the blank questions were scored 1 point for each correct component filled-in. The multiple-choice, the true-false, and the matching questions, were also scored 1 point for each correct response. When a justification was required, the response was taken as correct only if the corresponding explanation was also correct. Two simple recall (questions 1 and 2) as well as a tiered objective question (question 3) used in this study, are presented in Figure 5.

In the following diagram: **(a)** Fill in the six blank squares with the chemical formulas of the proper compounds, **(b)** Fill in the six blanks on the arrows with the reagents and conditions of the reactions, **(c)** Define the direction of the six undirected linking lines, **(d)** Fill in two more chemical reactions (draw the two arrows corresponding to those reactions and label the arrows with the reagents and conditions of the reactions).

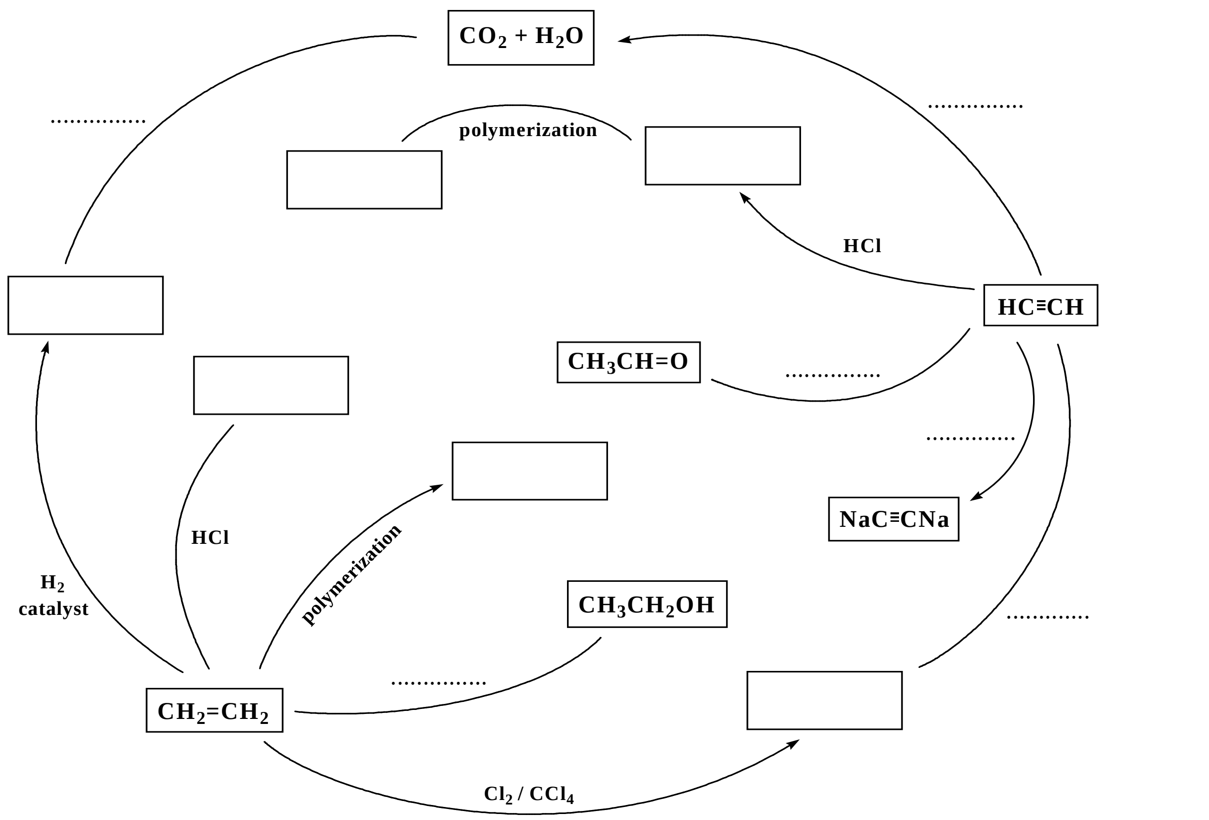


Figure 4: The SAQ included in the test B2.

Ninety-one (46 males, 45 females) 11th grade students from a public urban high school in Athens area participated in this study, which was conducted over a 3-month period. In the first stage, some basic organic chemistry topics were taught regarding organic compounds, i.e., the various classification schemes, the IUPAC nomenclature, and the constitutional isomerism. The applied procedure followed the same steps as the one described in the first research phase.

Results from the second research phase and discussion

Five systems thinking levels were revealed from students' responses on A2 and B2 SAQs. The distribution of students' responses indicates that most of the students (29 on SAQ-A2 and 35 on SAQ-B2) demonstrated a "complex connection" level, namely they were able to identify two or more, but not all possible, parts/subsystems of a whole/system. A large number of students (26 on SAQ-A2 and 22 on SAQ-B2) possessed a "system" level, which enabled them to recognize all relevant concepts and possible links that constitute a meaningful conceptual whole. In the SAQ-A2 system, 9 students were classified in the "no connection" level, 14 students were classified in the "partial connection" level, and 13 students were classified in the "full connection" level. In the SAQ-B2 system, 6 students' responses demonstrated no scientific meaning, 14 students were classified in the "no connection" level, 8 students were classified in the "partial connection" level, and 6 students were classified in the "full connection" level.

1. Fill in the blanks in the following propositions:
(a) The organic compounds in which carbon atoms are connected only with single bonds are called …………… Such a compound is one that has the structural formula ……………….
(b) The constitutional isomerism is divided into..……………………. isomerism, ……………………… isomerism, and ………………………… isomerism.
2. Choose the right answer for each of the propositions (a) and (b) :
(a) By hydrogen addition in acetylene is formed :
i) ethane ii) ethine iii) ethanol iv) ethanal
(b) Which of the following is a reaction by which alkenes are formed?
i) polymerization ii) photochemical halogenation
iii) alcohol dehydration iv) hydrogen addition to alkanes

3. For two hydrocarbons, X and Y, the following information is known:
- They both decolorize a solution of bromine in tetrachloromethane.
- Hydrocarbon X reacts with sodium.
- By hydrogen addition to hydrocarbons X and Y the same compound is formed.

Accordingly, which one of the following propositions is correct?
Explain why the other three propositions are false.
(i) Hydrocarbon X is ethene and hydrocarbon Y is ethine.
(ii) Hydrocarbon X is propine and hydrocarbon Y is ethene.
(iii) Hydrocarbon X is propane and hydrocarbon Y is propene.
(iv) Hydrocarbon X is ethine and hydrocarbon Y is ethene.

Figure 5: Three objective questions used in the second research phase.

The Pearson's correlation coefficient (*r*) was calculated to determine extent of the association between the two scoring methods used for SAQs. A very strong positive correlation was found between the scales ($r = .93$ for the SAQ-A2 and .94 for the SAQ-B2, respectively). It is obvious that, independently from the SAQ content, both scoring schemes led to almost identical results. Consequently, the more practical numeric scoring scale was used for further statistical analyses. Items' construct validity was tested using exploratory factor analysis. For both tests (A2 and B2), the values obtained from the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy indicated the appropriateness of the factor models. Principal component analysis and scree- plot resulted in two common factors which were subjected to a varimax rotation. An item analysis was also conducted for a better interpretation of the results. For the objective items, an analysis of their meaningful understanding components based on their content and task requirements was also conducted. The item analysis showed acceptable difficulty and discrimination index. The "item-total score" correlations were also calculated using the Pearson's correlation coefficient (*r*). The results indicated that all items contribute to the validity of the tests. Moreover, the reliability of internal consistency was calculated for each test. The Cronbach *a* was found to be 0.87 for the test-A2 and 0.84 for the test-B2.

Taking under consideration the items' content and requirements, the more reasonable interpretation of the factor analyses results for both tests is that, the first factor is the "meaningful" one while the second is the "rote". In the test-A2, the objective items requiring just recall of chemical information were strongly loaded on the "rote" factor, as expected. The remaining objective items were strongly loaded on the "meaningful" factor. These items required not just the recall, but also the activation of some cognitive skills that are necessary for successfully applying knowledge in specific situations, capturing in this way aspects of students' meaningful understanding. For correctly answering these items students should have develop sufficient representational skills and they should be able to apply their conceptual knowledge on specific examples. Regarding SAQ items, three out of four items of the SAQ-A2 (items a, b, and d, see Figure 3) were strongly loaded on the "meaningful" factor. The item c, which asked from students to define the direction of the undirected linking lines in the diagram, was almost equally loaded on both factors.

In the test-B2, the multiple-choice and the true-false items, which were designed to assess recall of knowledge, were loaded on the "rote" factor, confirming our assumptions. The remaining questions required cognitive skills beyond simple recall, such as to draw chemical information from symbolic chemical representations and to link chemical information in order to make judgments, identify relationships, or draw conclusions. Three of the SAQ items (a, b, and d, see Figure 4), and the two-tiered objective questions (see, for example, question 3 in Figure 5) requiring a brief explanation, were all strongly loaded on the "meaningful" factor. Although the SAQ items were also moderately loaded on the "rote" factor, their loadings on the "meaningful" factor were clearly stronger.

Finally, the Pearson's correlation coefficients (r) were calculated for the two variables, the total SAQ and objective "meaningful" items scores in both achievement tests, and strong positive correlations were observed ($.68 < r < .77$).

Overall, a variety of tests supported the validity and reliability for the two proposed assessment schemes. The difficulty and discrimination indexes, the "item-total score" correlations, and the calculated Cronbach *a* values, indicated that the two applied assessment schemes have acceptable psychometric properties and are suitable to be used as assessment tools in high school. All the factor analyses results related to the objective items under study indicate that properly designed objective questions are valid and reliable tools for assessing students' meaningful understanding of organic chemistry concepts. The results suggest that the tiered objective questions as well as other types of objective questions requiring from students the application of conceptual knowledge on specific examples for interrelating organic chemistry concepts, explaining an answer, or translating and constructing symbolic chemical representations, were found potentially effective tools for eliciting aspects of students' meaningful understanding in organic chemistry. This fact shows that a properly design objective assessment scheme can be a valuable tool for both classroom assessment and research purposes as well [18].

Regarding SAQs, it is noticeable that, although the content of the two SAQs was different and more representational competence is required in SAQ-B2 that involves exclusively symbolic representations of organic reactions, similar results were obtained for the two SAQs (A2 and B2) in factor analyses. This is preliminary evidence regarding the potential of the proposed systems thinking assessment framework for a more general and extensive use. A challenge for future research would be the evaluation of SAQ items having an exclusively linguistic format, i.e., not incorporating symbolic representations, and assessing other chemistry topics as well, as for example a general or inorganic chemistry topic.

The results from the factor analysis procedures showed that the SAQ items, designed to assess students' systems thinking skills, were mostly loaded on the same factor with the objective items that were constructed to capture aspects of students' meaningful understanding in the organic chemistry domain. Moreover, strong correlations were observed between the total SAQ and objective "meaningful" items scores. This significant association indicates that the systems thinking level developed within a science domain is strongly related with a deeper understanding of relevant science concepts. This association certainly worth further investigation, as it may indicate new aspects concerning students' understanding of chemistry in relation to systems thinking.

Finally, although students' responses on the two assessment schemes were found to be significantly interrelated, each scheme was developed based on a different approach and therefore it can provide different information regarding students' cognitive structure. A combination of the two assessment schemes gives a potential of a more multifarious evaluation of students' conceptual understanding and knowledge integration. Such a multidimensional assessment, in combination with the appropriate learning environment, should provide more opportunities for students to develop meaningful understanding in a scientific domain.

CONCLUSIONS

The results of a research project carried out regarding the development and evaluation of a systemic assessment framework based on SAQs, showed that the psychometric properties of this assessment scheme are acceptable. It was found that SAQs' specific characteristics, i.e., task format, diagrams' complexity, and cognitive demands, play a significant role for this scheme in order to efficiently assess students' meaningful understanding in organic chemistry. The SAQ scheme was also found to be a valuable strategy for capturing students' systems thinking skills in an organic chemistry context. A significant association was observed between students' performance on SAQs and on objective items designed for assessing meaningful understanding. This association reveals that the students' systems thinking level developed in organic chemistry is strongly related with a deeper understanding of the relevant science concepts. It is underlined that students' understanding of chemistry in relation to systems thinking certainly worth further investigation.

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