Acid-Base Chemistry Experiments and Societal, Individual, and Vocational Aspects of Students’ Learning

Author Name,\*

Affiliation and address

Abstract

This study examined how the relevance of chemistry experiments about acids and bases affected the societal, individual, and vocational aspects of students’ learning. The sample included four high-school classes and the study focused on analyzing the difference between students who had studied acids and bases by the experimental method and those who had studied it using a more traditional method. A total of 112 students participated in the study, 57 (51%) of whom were from the experimental class and 55 (49%) from the control class.

The study was conducted through questionnaires to determine whether a close connection exists between the relevance of experimentation regarding the topic acids and bases and the societal, individual, and vocational dimensions of student achievement. It can be concluded that the impact of the relevant learning on students’ societal, individual, and vocational aspects is positive, enhancing the achievements and status of each aspect. Regarding the individual aspect, the teacher develops skills and increases the students’ motivation and enjoyment and improves their achievements. Regarding the vocational aspect, the teacher utilizes innovation and skills to achieve relevant learning; regarding the societal aspect, the relationship between the students in the classroom is strengthened and their positive self-experience increases.

Graphical Abstract

Keywords

Relevance in Science Education; Experiencing Experiments; Acid-Base Experimentation; HRA vs. LRA; Chemical Education Research

Introduction

High-school students’ attitudes toward science subjects are not positive in general; their motivation to succeed in science is low and there is minimal reference to science as a subject with social aspects. Students want to conduct more experiments in science in order to succeed in their professional life.1

We are constantly trying to solve unanswered questions about phenomena in our daily lives or other things that arouse our curiosity and divert our attention.2 We often try to discover the world around us and to cultivate our skills alone, without sharing with others the unique world that we are trying to create.

Many studies have presented a bleak picture in relation to styles of learning science, especially at the high-school level. A key argument is that science education—especially physics and chemistry—is unpopular with students.3 Some of these studies indicate that students are not sufficiently interested in chemistry or are unmotivated to learn chemistry concepts. Learners often view chemistry as irrelevant to both themselves and the society in which they live.4

According to Bretz,5 there is no evidence to support the hypothesis that instruction designed in response to students’ learning requirements can improve achievement. On the other hand, Towns described how Kolbe’s learning styles were particularly well-suited to learning in a chemistry lab.6 Pashler and colleagues reported that learning is tailored when instruction is appropriate for the learner’s preferences and abilities.7

Therefore, science teachers in general, and chemistry teachers in particular, should strive to make their lessons more relevant, in order to improve students’ motivation and to interest them in the subject.8 One of the ways to make science topics more interesting to learn and to raise students’ level of motivation is to link experiments and products to problems, solutions, and challenges of daily life.9 However, teachers may not know what is meant by “making science more relevant.” The connections (or differences) between terms such as relevance, interest, and motivation may need clarification.10 In 2013, Stuckey and colleagues published a review on the subject11; in 2015, Eilks and Hofstein edited a book in which they analyzed the concept of relevance and proposed a schematic framework relevant to scientific learning.12

Three relevant aspects of science education have been proposed: societal, individual, and vocational11:

The ***individual dimension*** focuses on adapting the subject to fit learners’ curiosity and interests, providing students with necessary and useful skills for dealing with their current and future daily lives, and contributing to the development of intellectual skills.

The ***societal dimension*** focuses on preparing students for self-definition and achieving a leading life in society by understanding the interdependence and interaction of science and society, and by developing skills for social participation and the ability to contribute to the development of a sustainable society.

The ***vocational dimension*** focuses on providing an orientation for future professions and careers, preparation for additional academic or professional training, and opening up professional opportunities (for example, by providing courses and achievements acceptable to higher education institutions).

These dimensions are neither entirely complementary nor contradictory; rather, they are connected to each other and partially overlap. For example, focusing on career orientation may develop personal curiosity as well as meet the future demand for more scientists and engineers. The latter is directly related to the idea of a thriving economy and the effective development of a company, for example.

It is generally agreed that in order to make learning more relevant to both the students’ lives and the society in which they live, it is important to change the content and the pedagogy of chemistry teaching.11,12 According to Garforth,13 few courses are based on the experiences students bring from their daily lives and this is much more true in chemistry than in physics or biology, for example.

The model of Eilks & Hofstein clarifies the interpretation of the various dimensions (societal, individual, and vocational) with respect to science education.12

Burmeister and colleagues proposed using appropriate modules and pedagogies in an attempt to make chemistry learning more relevant and interesting.14 These modules and pedagogies are integrated into the development of teaching units and their implementation in schools, in order to promote the professional development of chemistry teachers. During the 1980s, when chemistry was based on the context of many chemistry curricula, experiments in some courses were based on students’ daily lives.13

High-school chemistry classes often use abstract concepts and unfamiliar language; as a result, students do not see the interesting relevance or importance of chemistry in their daily lives outside of school or in terms of their future role in society. The chemistry topics taught in schools should help students understand and use basic chemical concepts as well as relate these concepts to real-world topics. In addition, lessons should demonstrate how chemistry applies to familiar topics such as food chemistry, climate change (e.g., acid rain), and more.15,16

Hugerat and colleagues analyzed how the chemistry concepts learned by tenth-grade students aligned with their daily lives and compared two teaching approaches: the low relevance approach (LRA) and the high relevance approach (HRA) (Figure 1).17 HRA is an exchange process based primarily on students’ life experiences—for example, kitchen chemistry, food chemistry, and so forth—and LRA is a traditional process.

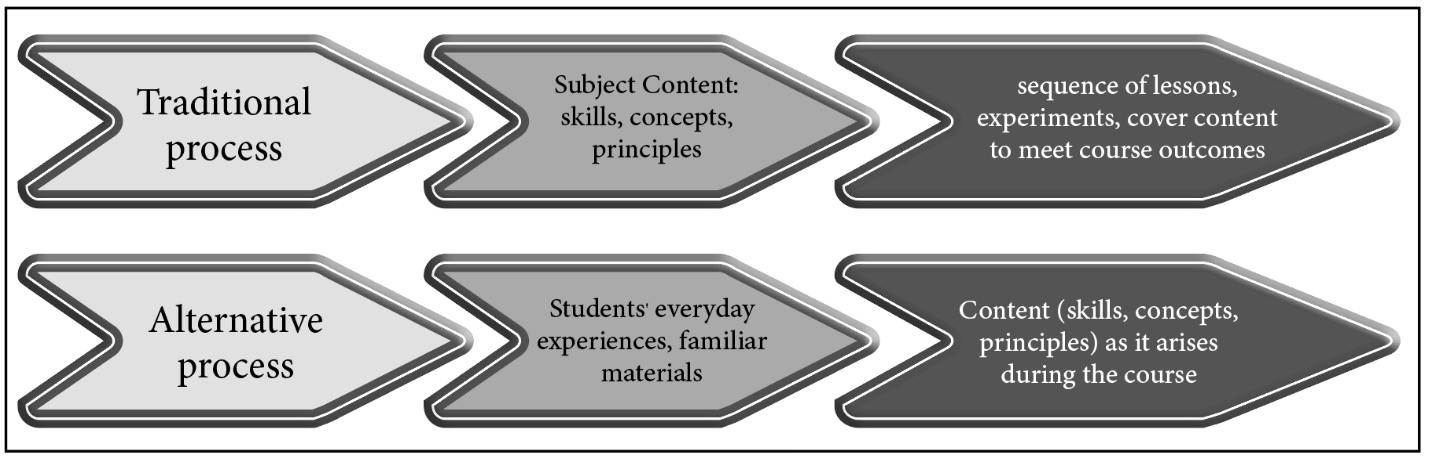


Figure 1

The researchers emphasized the relevance to students’ daily lives of various chemistry topics. Following the intervention program, students’ motivation, with respect to their perception and satisfaction, attitudes toward chemistry, and academic achievements in chemistry were assessed to determine what impact that the teaching style had. It was clear that using relevant experiments in chemistry significantly contributed to the learning variables and that teaching chemistry topics using the HRA method led to an improvement in student motivation, awareness, and performance, as well as improving their attitudes toward science and its learning, compared with the LRA approach.17

According to a study by Fensham and colleagues,18 this type of science education helps students learn and understand the relationships between science and society and develops skills that will encourage them to participate in future scientific discussions and decision-making processes. With this type of science education, the students are also required to learn challenging scientific skills.19

These two approaches were compared statistically and it was concluded that chemistry teachers should make chemistry education more relevant in order to increase student motivation. The relevance of science education can easily be adapted and interpreted to the field of chemical education as well, since it is part of science education in general, according to the three aspects defined above.16

Comparison Between an Exchange Process and a Traditional Process: Making Acid-Base Concepts More Relevant

Learning through the HRA method reinforces the three aspects—societal, individual, and vocational—which allows students to learn topics or concepts relevant to their daily lives. Using common materials to explore the chemistry of everyday objects (for example, for the acid-base topic, using vinegar and baking acid as acids and baking soda as base17) matches the curiosity of learners and cultivates in them different personal skills; relevant science studies encourage independent leadership in society, by better understanding the interaction between society and science.20 Regarding the vocational aspect, this method provides an orientation to future professions and careers and preparation for academic or future professional training, and opens up professional career opportunities.

In contrast, using a traditional LRA method does not reinforce the three aspects. For example, the student learns about acids and bases using the lesson’s activities, learning experiences, and content during the course, but the materials used are not encountered in students’ outside lives.21,22

Siegel & Ranney’s research had two objectives: (a) to design and test new tools capable of reflecting changes in attitudes toward science over time and (b) investigation—to determine the effect of two similar curricula on the relationship between two groups.23 The basic results showed that, on average, students had a slightly positive outlook to science, and that it became more positive during the semester. In addition, qualitative analysis using a head scale showed that the gains in both classes were modest but appreciable.

These findings are interesting, not only because they indicate the success of the curricula, but also because they show that students’ beliefs about the relevance of science can change even within one semester, simply by educators’ use of realistic, interest-oriented scientific activities. This is particularly critical because students’ attitudes affect their future involvement and performance in science classes and in their careers.23

Teachers’ Perceptions of How to Teach Acids and Bases

Lembens & Reiter argued that in order to teach about acids and bases, teachers should rely on (among other things) a proper understanding and use of particle perception, think in terms of models, and deal with different historical approaches, as well as plan and design appropriate experiments.24 In addition, teachers need to know how learners perceive the teaching and learning of this topic. For this reason, teacher educators should receive proper training, as well as apply and reflect on the knowledge and skills needed to build and sustain teachers’ professional knowledge and skills.

Unfortunately, many students still have misconceptions about acids and bases and confuse different models. A very common problem is the fact that many students use the terms “acid” and “acid solution” as well as “base” and “basic solution” as synonyms, without being aware that they are referencing the particle level when they refer to an acid. When they refer to an acidic solution, students are confused with regard to the hydrogen ions; when they refer to the properties of hydroxide ionic acids and to the properties of bases, they do not perceive that they are mixing two different and incompatible models.25

To systematically investigate for ourselves how these specific difficulties manifest, we began to develop an analytical framework for analyzing the micro-educational (micro-learning) videos in order to identify and better understand the main problems of student teachers when they learn to teach about acids and bases.26

The next steps towards developing and learning effective education opportunities in the context of acids and bases are to review the most common textbooks used for primary and secondary chemistry studies; conduct interviews with experienced chemistry teachers to further validate the analytical framework for micro-text analysis of areas; identify and characterize teachers’ main barriers; develop, examine, and refine effective learning sequences; and finally, create a didactic program based on fruitful and effective teaching in the context of acids and bases.

This study addresses three questions that examine the relationship between the relevance of “experiencing experiments” in the acids and bases chemistry class and their impact on the societal, individual, and vocational aspects. We formulated hypotheses and a study based on collecting quantitative data, using questionnaires and scores with a group of eighth graders.

Methodology and study participants

The researchers were transferred during the 2019–2020 school year and included the following moves:

Building the intervention plan in coordination with a standard document in chemistry.

Coordination with the teachers at the school.

Activities with acids and bases based on the curriculum and the standards document using materials that are relevant and familiar to students.

An acid and base study unit (intervention plan) was built that included six 45-minute lessons on the following topics:

1. Acid-base definitions (Lessons 1 and 2)
2. Producing acids and bases (Lesson 3)
3. pH scale (Lesson 4)
4. Acid-base reactions and neutralization reactions (Lessons 5 and 6).

The study unit was prepared using the LRA and HRA.

Low Relevance Approach

The student learns about acids and bases in a method sequence of lessons, activities, and experiments, and covers the content to meet the course requirements. The materials used in the experiments, such as HNO3, H2SO4, NaOH, and HCl, are not from daily life.

Students learn about titration between an acid (HCl) and a base (NaOH) when the indicator is phenolphthalein or litmus paper, materials unfamiliar to them from their everyday life. Additionally, students learn about the pH scale, different types of acids and bases, and the reactions between them; however, the students encounter none of these topics in their daily lives. Students learn about the preparation of acids and bases by the reaction between different chemical oxides and water.

High Relevance Approach

These students study the acid-base concept in a manner relevant to their everyday lives using materials such as vinegar and baking soda, materials that are used every day or that represent the chemistry of everyday objects. The indicator used to identify acids and bases and when performing titrations is red-cabbage juice, which is derived from red cabbage salad, a popular salad in Israel. It should be emphasized here that students use materials with which they are familiar.

The students also learn about acid production using the acid rain example: SO2 is emitted because of the burning of fuel oil with a high sulfur content. Chemicals and fertilizers such as nitrogen oxides (NOx) are emitted during the process of producing HNO3.

Students build their own pH scale using the obvious visible changes to the red cabbage juice along with acids and bases from their daily life. In this activity, the social side of the activity is strengthened when the students need to cut the red cabbage and then discover that their hands are stained. They must collaborate to decide how to prepare an indicator solution and they discover that the color varies with the pH of the solution.

Study Population

The semi-experimental study included 112 eighth-grade middle school students in an Arab village in northern Israel. Two experimental classes (57 students, 51%) studied the subject of acids and bases using the HRA method and two control classes (55 students, 49%) used the traditional LRA method.

Collecting and Processing the Data

The study was of mixed design: both quantitative and qualitative. In the quantitative part, data were statistically analyzed with SPSS v23 software. The study was designed to provide causal explanations and predict future behaviors based on present behavior, as well as to gain an understanding of phenomena, with a comprehensive approach to diverse and latent aspects of human behavior and the set of interactions that characterize this behavior.

The first study was a questionnaire for the experimental group only, in order to examine the societal, individual, and vocational aspects, and the second research tool was a test for both groups that included an experiment to test students’ scores in chemistry. Both studies compared results before and after the course.

The first study used a questionnaire that examined the attitudes of the ninth-grade students who participated in this study, including the control group, regarding the societal, individual, and vocational aspects. The questionnaire was constructed on the basis of Stukey & Eilks’ studies,27 with improvements to fit the current study, and validated in accordance with accepted academic standards. This questionnaire contains statements about the individual dimension with Cronbach’s alpha 0.838 (for example, “topics in science classes are very important to me for my daily life”), statements about the vocational dimension with Cronbach’s alpha 0.772 (e.g., “science classes are always about forming and building materials”), and statements about the societal dimension with Cronbach’s alpha 0.806 (e.g., “the topics in science classes are very important to society”). The questionnaire did not have opposite items. Students were asked to rate each item on a Likert scale between 1 (strongly disagree) and 5 (strongly agree). The questionnaire was found to be reliable and valid in previous studies (Cronbach’s alpha 0.83–0.89)27; we found reliability to be higher (0.934). The higher the scores on the questionnaire, the more positive the attitudes.

The findings were analyzed according to the mean scores, the charts between the control groups and the experimental groups, and t-test calculations, as well as Cronbach’s alpha and other statistical analyses.

In addition, a structured interview was conducted. Qualitative data were collected for the students’ responses and questions during the implementation of the relevant method: during the activity, the teacher began creatively and with titles that inspired students’ questions and asked about the context. The questions and statements of the students during the lessons were collected and analyzed, to link them with the quantitative results.

Results

In both the groups, students’ grades in chemistry were tested before and after the acid-base topic was studied. The mean score of the students in the LRA control group was lower than that of the students in the HRA group, who scored a mean of 80% on the test.

Table 1 indicates the student responses to questions about the individual aspect of their learning. The two groups showed an appreciable difference regarding personal views of the effect of learning useful science in students’ daily life (T = 3.1.35; p<0.01). That is, relevant science experience improved the individual aspect of students’ lives.

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| --- | --- | --- | --- | --- | --- | --- |
|  | | Table 1. Student Responses on a Four-Point Scale Regarding the Individual Aspect of Learning | | |  |  |
| Category | Experimental group | | | Control group | | T |
|  | Mean | | Standard deviation | Mean | Standard deviation |  |
| Much of what I learn in science classes is useful in my daily life today. | 2.5 | | 1.31 | 2.1 | 0.45 | -5.2- |
| Learning science can help me when I buy food. | 1.9 | | 0.4 | 2.1 | 0.37 | 1.5 |
| Caring for people can involves a scientific choice, such as using pesticides on plants. | 2.05 | | 0.39 | 1.83 | 0.4 | -4.06- |
| Science helps me make wise decisions. | 1.7 | | 0.29 | 1.5 | 0.4 | 7.9- |
| The things I do in science have nothing to do with the real world. | 1.74 | | 0.25 | 1.16 | 0.3 | 4.6- |
| Science helps me make decisions that affect my body. | 2.1 | | 0.9 | 1.9 | 0.29 | 3.2- |

Regarding the vocational aspect, according to the results of Table 2, there is again a clear difference in the results between the control group and the experimental group, with the relevant learning method being more successful than traditional learning.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Table 2. Student Responses on a Likert Scale Regarding the Vocational Aspect of Learning | | | |  |
| Category | Experimental group | | Control group | | T | |
|  | Mean | Standard deviation | Mean | Standard deviation |  | |
| My parents encourage me to continue in science. | 4.4 | 0.73 | 3.1 | 0.44 | -3.56 | |
| I plan to take more science classes in high school. | 0 | 0.02 | 3.08 | 0.43 | 0.45 | |
| Science helps me work with others to find answers. | 5.3 | 0.719 | 4 | 0.43 | 0.1 | |
| Classroom science helps me evaluate my work. | 4.8 | 0.66 | 0.8 | 0.16 | 0.6 | |
| Studying science helps me understand the environment. | 5.1 | 0.69 | 3.8 | 0.42 | 0.39 | |
| Emotion has no place in science. | 6 | 0.82 | 2.1 | 0.32 | 0 | |
| Science will help me understand and judge other people’s perspectives. | 6.2 | 0.9 | 4.9 | 0.6 | 0.48 | |
| Science will help me understand more about problems around the world. | 1.3 | 0.27 | 5.1 | 0.7 | 0.54 | |
| Science has nothing to do with life outside of school. | 4.2 | 0.57 | 2.3 | 0.36 | -0.7 | |
| Experiments in science help me learn with a group. | 6.3 | 0.9 | 6.1 | 0.8 | 0.52- | |
| Science teaches me to help others make decisions. | 1.1 | 0.2 | 0.7 | 0.19 | 03 | |
| Knowledge of science will not help me in sports. | 5.1 | 0.6 | 1.3 | 0.25 | 0 | |
| Science has nothing to do with buying things, such as food and a car. | 5.3 | 0.75 | 5.1 | 0.66 | 0.3 | |
| Knowing science will make it easier for me to repair a bicycle. | 6.1 | 0.84 | 6.3 | 0.9 | 0.43 | |
| Science teaches me to think less clearly than I already do. | 5.5 | 0.79 | 6.32 | 0.95 | 0.1 | |
| Making a good decision is a scientific process. | 0.31 | 0.6 | 6.3 | 0.89 | 0 | |
| In class, science will help prepare me for college. | 0.31 | 0.62 | 6.3 | 0.9 | 0 | |

Table 3 shows that the groups differ regarding the societal view of the ability to help and better understand the world through experiments. Statement number 4, “Science will help me understand the effect I have on the environment,” revealed a difference between the control group and the experimental group, having a more positive response in the experimental group than in the control group. According to these findings, HRA is more successful and more positively affects the students than LRA.

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| --- | --- | --- | --- | --- | --- |
| Table 3. Student Responses on a Four-Point Scale Regarding the Societal Aspect Of Learning | |  |  | |  |
| Category | Experimental group | | Control group | | T |
|  | Mean | Standard deviation | Mean | Standard deviation |  |
| Classroom science helps me work with others to make decisions. | 5 | 0.61 | 3.1 | 0.44 | 0 |
| Scientific experiments can help me better understand the world. | 6.2 | 0.83 | 3.9 | 0.59 | 0.41- |
| Knowledge of science can help me protect the environment. | 2.9 | 0.42 | 5.1 | 0.63 | 0 |
| Science will help me understand the effect I have on the environment. | 6.2 | 0.83 | 5.9 | 0.79 | 0.44- |
| Science helps me ask others for help with my work. | 6.2 | 0.83 | 6.3 | 0.911 | 0.42- |
| Science should be required in school. | 6.7 | 0.94 | 6.1 | 0.8 | 0.4 |
| I am interested in a career as a scientist or engineer. | 5.3 | 0.7 | 5.1 | 0.64 | 0.4 |
| I have support from others to excel in science. | 5.1 | 0.69 | 6.2 | 0.89 | 0 |
| Learning science can help me understand about things that affect people’s health. | 5.3 | 0.75 | 5.3 | 0.68 | 0.36 |

In addition to the quantitative data produced by means of the questionnaires, a structured interview was conducted. Common answers from the students that studied acid-base concepts using the LRA indicate that many students are not very interested in school chemistry lessons. In fact, they wonder why they need to be familiar with chemistry concepts. Implementation of the HRA intervention programimproved students’ attitudes toward chemistry and its study.

Comments that were repeatedly given include:

**Student 1:** “Science helps in getting a better understanding of life and events. It had a positive effect on my understanding of chemistry.”

**Student 2:** “Giving examples from everyday occurrences, in order to help students gain a better understanding; connecting the subject with life.”

**Student 3:** “It makes me want to implement things in daily life; it exposes me to a variety of different topics, how they are used, their dangers, and their effects.”

**Student 4:** “I will continue to study science. It had a very positive influence and raised my motivation and my satisfaction; perhaps I might even become a chemistry teacher or scientist in the future.”

Discussion

Hypothesis 1: We Will Find a Close Connection Between the Relevance of Acid-Base Classroom Experiments and the Personal Aspect

The term “meaningful learning” distinguishes between valuable, experiential learning and memorization learning—memorizing facts that learners do not attach importance to, or practicing skills that learners do not see as necessary—which is often of no value.28 This type of learning is characterized by engaging the whole person, including their cognition and emotions, in the learning process. Such learning changes the behavior, attitudes, and perhaps even the personality of the learners.28

The mean score on the chemistry test taken by the two groups was 80% greater in the HRA group than the LRA control group (50%), showing the close relationship between relevant learning (experimental) and students’ perception and success on the test, which justifies the first hypothesis.

It can be concluded that relevant learning, combined with experiments, develops analytical and critical thinking as well as decision-making skills, while dealing with complex and realistic problems, and also improves students’ ability to argue and express themselves. In addition, it increases learners’ motivation and enjoyment and improves their achievement, thinking, expression of ideas and personal views, and creative self-esteem (a systemic approach in science teaching).17

The results in Table 1 indicate the significant difference between the two groups; this explains the significant difference in the test results regarding the greater impact of relevant learning than traditional learning. For example, in item 3 (“Caring for people can involve a scientific choice such as using pesticides on plants”), there seems to be a clear difference between the two groups regarding caring when making a scientific choice, which is encouraged more in the experimental group than in the control group.

These results attest to and justify the results of Hofstein and others29: studying science through research is recommended as an effective and authentic method to develop and build a knowledge base and a good understanding of scientific ideas and concepts. Moreover, it provides science teachers with a means of improving their teaching that will lead to an improved learning atmosphere.

The new standards that are being formulated in science education reflect the current vision regarding all that is known about content and pedagogy, in evaluating the learning atmosphere of students in the classroom and regarding the support needed to ensure quality education for all students. The pilot “Chemistry in an Exploratory Approach” program in Israel is essential and will improve the teaching and learning of chemistry.

The educational process aims to give students a sense of growth and value as well as ability, success, and personal fulfillment, in addition to experiencing discovery and responding to their curiosity. It develops them as active people who can integrate well into society and contribute to it. In order for the educational process to achieve its goals, the Ministry of Education promotes meaningful learning while meeting the required achievements, through a systemic, consistent, modern, controlled learning process. This is reflected in the curricula and the characteristics of the teaching–learning processes as well as the assessment and learning environments, in light of the role of adults and the functions (cognitive, meta-cognitive, intrapersonal, interpersonal, sensory-motor, and managerial) that the education system strives to develop in the students.30

Hypothesis 2: We Will Find a Close Connection Between the Relevance of Acid-Base Classroom Experiments and the Vocational Aspect

With respect to the vocational aspect, Table 2 shows that the two groups differed significantly.

It can be concluded that from a professional point of view, exams are planned for students and later can contribute to the economic growth of a company, for example, or help students focus on a potential career and help them to get a good, well-paying job.12

This justifies the statement of Hofstein and Lunetta,29 who in their study found that chemistry students who participated in this program were given unique opportunities to be actively involved in a worthwhile learning process. Research experiments in a chemistry lab have been concerned with changing and renewing the way chemistry is taught and learned and the way students are valued, and improving teachers’ professional development. The fact that the program grew from three classes to about 90 classes in the school year after the program was implemented provides evidence that teachers, students, and school administrations value this program.

Hypothesis 3: We Will Find a Close Connection Between the Relevance of Acid-Base Classroom Experiments and the Societal Aspect

The findings showed that HRA learning was more successful and had a more positive effect on the students than did the traditional LRA learning; this was reflected by the dominance of the experimental group rather than the control group in the questionnaire categories (Table 3).

Both groups showed a change regarding the ability to help and better understand the world through experiments. However, science was perceived as helping to understand environmental factors significantly more in the experimental group than in the control group.

One teaching strategy encourages problem-based learning. In the process of problem solving, students learn while they perform a variety of activities, including field trips, projects, and use of computers. The learning process requires self-experience or group work as well as dealing with errors by way of trial and error. This creates connections and a dialogue between students about chemistry discoveries. It can improve the experimental process as well as the results and also improve problem solving: working in groups is recommended in science classes in general, and in chemistry in particular.

Another teaching approach encourages research-based learning: learners are supposed to develop critical thinking, acquire argumentation skills, analyze data, and compare their findings with those in the literature.

Teaching socially encourages reflective learning: this means looking at the student inwardly and examining the learning from a reflective perspective, identifying and deciphering new situations that develop during learning, as well as self-criticizing and re-examining learning while the students talk by themselves and with others (in the group).31 This includes utilizing research skills in teaching science and technology from the time that knowledge was constructed, understanding the scientific content, and cultivating higher-order thinking and modern collaborative, creative, and critical skills. Teaching research skills and experiencing the entire process of scientific research enhances the motivation and enjoyment of learning science and technology. Teaching-learning-assessment processes integrate scientific research skills at all age groups.32

The lessons were constructed in a creative way so that the students asked questions, raised various issues related to the connection of the topic (acid-base) with the different issues (societal, individual, and vocational aspects). In an example from the HRA in teaching acid-base concepts, the instructor announced that the lesson would be about “red cabbage juice” as one example of an indicator for acids and bases. The students were asked: “What is the connection between red cabbage juice and the indicator for acids and bases?” This question initiated a context-based learning process. One of the student’s reactions was: “Only now do I understand how I will become a different teacher in the future.” Another student’s reaction was: “Now, I want to be a researcher in the field of food chemistry”. These students’ reactions clearly indicate that using HRA in teaching the acid-base topic supports the vocational dimension.

In another example, the instructor announced that today’s lesson would be about acid rain. The students were asked: “What is the connection between acid rain and the production of acids?” This question initiated a context-based learning process. One of the student’s reactions was: “I will be more active in the future in the field of environmental protection to save our planet”. Another student’s reaction was: “I want to be a researcher and develop methods that will reduce the amount of gases responsible for acid rain.” These students’ reactions clearly indicate that using the HRA in teaching the acid-base topic supports the social dimension and the vocational dimension.

In a third example, the instructor announced that today’s lesson would address the question “is every transparent liquid water?” The students were asked: “What is the connection between this topic and the acid-base one?” This question initiated a context-based learning process. One of the student’s reactions was: “This topic increased my interest and curiosity to think about the subject of acids and bases.” Another student said: “This topic made me think deeply about transparent and acidic fluids encountered in everyday life.” These students’ reactions clearly indicate that using the HRA in teaching the acid-base topic supports the individual dimension.

The students’ responses led us to conclude that learning chemistry using the HRA had a very positive effect: it made them appreciate the subject, made it seem less difficult, and made it more interesting and attractive. Stuckey et al.11 reported the contribution to the three dimensions: individual (student 1 and student 2), social (student 3 and student 3), and vocational (student 4). These dimensions raised the level of motivation and satisfaction among the students, mainly because of their more positive attitudes toward chemistry due to the connection made between chemistry and their daily lives.

Conclusions

It can be concluded that relevant learning has a positive impact on personal, vocational, and social aspects of students’ lives, enhancing the achievements and status of each aspect. The personal aspect develops skills, increases the students’ motivation and enjoyment of the subject, and improves their achievements. The vocational and social aspects strengthen the bond between students in the class and increase their self-experience.

***The personal aspect:*** Learning through the “relevance of the experiments”, the students expressed that much of what they learn in science classes is useful in their daily lives. In addition, the relevance of the experiments encourages curiosity, satisfaction, and interest among the students and improved their responsible behavior and competitiveness.

The ***vocational aspect***: The students were better able to pass exams for the next education level owing to the relevance of the experiments in the chemistry classes. This success later contributed to the economic growth of companies, enabled students to focus on potential careers, and helped students get a good paying job.

***The societal aspect:*** Learning with a group helps students understand and judge other people’s perspectives. Students were encouraged to work with others and to determine which scientific experiments can help them better understand the world. Students were able to learn how to behave in society, behave as responsible citizens, find their personal place in society, and advance their social interests.

AUTHOR INFORMATION

Corresponding Author

\*E-mail:

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