METACOGNITION IN CHEMISTRY EDUCATION

Abstract: The study determined the cognitive and affective effects of metacognitive activities. Specifically, it sought answers to define the subjects’ chemistry performance, motivation, and scientific attitude before and after the exposure to the intervention, to find out the significant improvement in the given parameters, and to design improved instructional activities in the light of the findings. The quasi-experimental study used the one group pretest-posttest design to answer the problems posed. At the outset, the cognitive and affective levels of the 42 subjects were determined. To find out the cognitive effects, a chemistry performance test developed by the researcher and validated by panel of experts was used. Chemistry Motivation Questionnaire and Science Attitude Inventory II were used to determine the subjects’ affective status. After the intervention period, the subjects’ exit competence was determined and differentiated from the pretest level. Through the t-statistic for paired observations, the difference between the tests was computed for the level of significance. As the final output, an enhanced instructional guide on integrating activities for metacognitive development among chemistry students was developed. There are seven metacognitive activities that were utilized in the present research undertaking, namely: Learning Portfolio (LP), Metacognitive Planning/Feedback/Discussion, Metacognitive Wrapper, Session Reflection Log, Goal-setting, Metacognitive Note-taking, and Learning Community. The activities correspond to specific episodes of the instructional cycles and were tweak with the intent of purposefully helping students develop metacognitive skillfulness. It is recommended that related studies be explored to determine the effect of a prolonged exposure of the students to the different metacognitive activities. Chemistry teachers may also adopt activities which are known to effectively assist students in conceptual development of abstract concepts in Chemistry and if situations permits, subjects be taught with laboratory following the science inquiry philosophy. Further, course and class advisers should encourage students to write their goal statements. Schools should also provide ample and varied opportunities for students to succeed and move up in the academic rung. Schools can design online or semi-online platform to cater to working students, second coursers, and working professionals whose circumstance could hamper in their maximum compliance and access to classroom activities. Lastly, to make science relevant to career and the personal lives of the non-science majors, academic programs such as environmental science or science, technology, and society may be offered in lieu of non-laboratory Physics and Chemistry.

Key words: Metacognition, Chemistry, Education, Pedagogy, Philippines, Cebu City.

Language: English

Citation: Abarro, R. Q., & Asuncion, J. E. (2021). Metacognition in chemistry education. ISJ Theoretical & Applied Science, 03 (95), 1-22.

DOI: https://dx.doi.org/10.15863/TAS

Scopus: ASCC 3304.
Introduction

The need to teach our students to become self-propelling learners has become a global catch-cry. However, if our classrooms are to succeed in this tall order, we have to regard our students as partners in facilitating learning. They have to be taught as good managers of their own successes in the classroom and beyond. Our pedagogical processes should be designed so as to empower students to effectively manage their own learning. Students should share a sense of accountability of their own academic success. Processes such as planning how to approach a course or a chunk of topic, monitoring one’s progress in the course including taking necessary steps for improvement after a thoughtful reflection of the learning experience should be manifested in our classrooms. In actual practice though our classroom processes presupposes that teachers do the planning, monitoring, and evaluating activities in the classroom to ensure students’ academic success. Many teachers would agree that when students exercise these functions success rate in the classrooms is likely to increase. The researcher believes that every student under proper training and feedback will consciously endeavor to become self-propelling learners: learners as “reflective practitioners” of his or her own learning. The key for this cogent point is teaching for metacognition. Metacognition is a term used to mean one’s thinking about his thinking processes or what cognitive psychologists consider as second order cognition. Purposive thoughts about one’s own thought processes or reflecting the different events and actions in life and their ramifications are few instances when one becomes metacognitive. Recently, though, it has come to encompass variables in the affective realms and the learners’ conscious and deliberate intent to do self-regulating processes (Louca, 2008). Reviewed researches around the globe echoed the impact of metacognition in promoting learning in the different disciplines (Pulmones, 2002, Lin et. al, 2005, Cooper, 2009, Chalmers, 2009, Chalmers &Nason, 2003, Tanner, 2012).

In the classroom settings, instructors can help students develop metacognition by asking them about their learning processes and reflect on what they practice (Anderson, et. al., 2010). Along this line, Cornford (2012) suggests that learning events in the class must provide activities that will compel students to be reflective learners. This can be done through assessments of one’s weaknesses or strengths and drawing lessons from such an experience. In fact Pulmones (2015) found out that when students are exposed to this kind of activities rather than in straight forward manner, students did not only enjoy it, but they also showed improvement in terms of performance and metacognitive skillfulness.

Recent studies have explored on how activities that foster metacognitive development can be integrated in different courses in the tertiary level viz:

- Promoting Student Metacognition in College Biology Course, Tanner 2012; The use of metacognitive wrappers in chemistry assignments, Lovett, 2008; Designing Metacognitive Activities, in 2001; Teaching Chemistry in metacognitive environment, Pulmones, 2007. Their findings tend to suggest the effectiveness of these activities in promoting the cognitive and the affective aspects of learning the course. Two constructs which are very important if we were to imbibe our students with life skills.

- Attitudes and motivation are two essential affective components that are known to influence students learning (Sirhan, 2007). These variables are in fact intertwined. One who has positive attitude towards learning tends to be motivated and thus may put more effort in the different learning tasks. In fact students who have high self-efficacy exemplified great performance in different learning tasks (Nolina, J. B., & Viko, B., 2010).

One of those learning areas that could benefit from this nascent development in pedagogy is the general education courses particularly conceptual subjects such as Chemistry.

Chemistry is of the branches of natural sciences. Its role in shaping the technological landscape cannot be denied. Because its contribution permeates in the realm of other sciences such as Biology, Physics, Nutrition, Health and other disciplines, it is often regarded as the central science. However; against this backdrop, chemistry education as an academic discipline is in decline internationally. Similar trends have been observed across the globe. Price & Hill (2004) reported in their surveyed literature in chemistry education this alarming pattern in Japan, Australia, Unites States, and the United Kingdom. In the Philippine tertiary schools Chemistry is taught as one of the general education courses together with physics, biology and geology. ‘The chemistry portion presents the basic theories and principles of chemistry, their historical development and applications (Padolina & Magno, 2015 ). Chemistry is oftentimes perceived as a difficult subject – a shared assessment of students in secondary and higher institutions of learning. This is even true particularly to non-science major students whose only compelling reason to take the course is graduation (Breuer, 2002). This observation is particularly relevant in as much that students who are enrolled in the researcher’s classroom are non-chemistry major. Oftentimes, students, especially those who have unpleasant high school chemistry experience, meet the subject with much skepticism and resistance.

The difficulty can be attributed to the students’ failure to have a theoretical grasp of the chemistry lessons (Sirhan, 2007 and Ali, 2014). Although, there are several variables to consider why meaningful learning in chemistry classroom is scarce, reviewed literatures would agree that the main obstacle lies in the students’ shallow understanding of the
fundamental concepts of the course. These difficulties block the students’ ability to effectively navigate in a deeper investigations and more demanding investigation in the course (Sirhan, 2007 p4 and Alir, 2014).

The problem is even confounded by the nature of students who enter our classrooms. As observed by the researcher, being a teacher for almost ten years and from information gathered from interviews with the student welfare and guidance offices personnel, it has been noted that students in his workplace generally show poor study habits, that is, planning for their lessons and other study strategies for survival in the rigorous demand by the academe and later on as an IT (information technology) professional. This is understandable because of the open admission policy of the school.

Analyzing the academic performance of students in science subjects, that is, physics and chemistry from 1990’s up to present would show that failing percentage revolves around 1% to 8% of the population enrolled in every semester with few exceptions on two or three semesters when the failing percentage has reached 14 to 16 percent. Closer data analysis; however, showed that while students indeed passed these science subjects, majority of them clustered in the segments with grades of 2.5 to 3.0. This means that students are struggling to grasp the concepts in physics and chemistry. Whether the cause is cognitive in nature or how ready the students are in facing college science academic demands or students’ attitude toward science and science instruction, this dismal performance calls for some reforms.

This bleak reality calls for restructuring of teaching-learning processes in such a way that both conceptual understanding of the course is achieved as well as the development of the life skills that are transferable across the disciplines or even in the personal lives and career of the students beyond the academia. It is the contention of the researcher who is handling introductory chemistry course in a tertiary institution that instructors should purposefully incorporate and emphasize activities that promote metacognitive skillfulness among students. It is with these two fronts; teaching for chemistry understanding and teaching for metacognition (or teaching for metacognitive skillfulness) that the researcher has embarked in this study.

Methodology
This study aimed in finding out the cognitive and affective effects of metacognition. The present study used the experimental design specifically the one-group, pretest-posttest design to find out if there was a significant difference in Chemistry1 students’ chemistry performance, metacognitive awareness, motivation, and scientific attitude before and after the exposure to the metacognitive activities.

The research subjects were second year students enrolled in Chemistry 1 course, first semester, school year 2016-2017. They were students who were in their third semester (second year, first semester) in the Information Technology program.

Verbal and non-verbal abilities. The researcher requested the profile of the participants from the office of the guidance and testing center of the school. As shown in the report, 69.23% of the total research participants manifest difficulty in perceiving the relational aspects of words and word combination. They also have trouble in understanding subtle differences among similar words and phrases as well as manipulate words to produce meaning. Data based on relevant psychometric test also showed that they have difficulty in using number to predict outcomes according to computational rules. However, around 38.46% of the students are able to comprehend and employ numbers that make them understand its relationship and manipulate spatially.

The current study attempted to find out the cognitive and affective effects of metacognition. To describe and measure the extent of effects of these variables the following tools were utilized in this study:

**Cognitive Effect**
Chemistry Achievement Test. To obtain the performance profile of the students in chemistry, a teacher-made test was used in this study. To ensure the validity and reliability of the test, the expertise of colleagues and other specialist in the field was sought. To check for readability and clarity, the tool was pilot tested to science major students of Cebu Normal University. Appropriate corrections were carried out based on the suggestions and recommendations both by the students, in terms of “comprehensibility” and usability of the tool, and the experts in terms of the validity of the items until a reliability index of α = 0.89 is achieved.

**Affective Effect**
Science Motivation Questionnaire (SMQ) by Shawn M. Glynn and Thomas R. Koballa, Jr. This Likert-scale questionnaire developed by Glynn and Koballa was used in this study to assess the motivation profile of the students. It is a checklist with thirty (30) statements and corresponding responses of never (1), rarely (2), sometimes (3), often (4), always (5). The thirty item-science motivation questionnaire is subdivided into six components of motivation, namely: (a) intrinsically motivated chemistry learning (items 1, 16, 22, 27, 30); (b) extrinsically motivated chemistry learning (items 3, 7, 10, 15, 17); (c) relevance of learning science to personal goals (items 2, 11, 19, 23, 25); (d) responsibility; that is, self-determination for learning chemistry (items, 5, 8, 9, 20, 26); (e) confidence; that, self-efficacy in learning science (items 12, 21, 24, 28, 29); and, (e) anxiety
about chemistry assessment (items 4, 6, 13, 14, 18). The items about chemistry assessment are reversed scored. The SMQ maximum total score is 150 while the minimum is 30.

Scientific Attitude Inventory (SAI II). The Scientific Attitude Inventory II developed by Richard W. Moore and Rachel Leigh Hill Foy was utilized to assess the students’ scientific attitudes. The SAI II has 40 Likert-type attitude statements and 12 position statements. Six positions are positive and are labeled 1-A through 6-A. Six are negative and are labeled 1-B through 6-B. The A and B pair for each position are opposites of each other. The useful scales for analysis are 1-AB through 6-AB for each position and the positive and negative scales consisting of 1-A through 6-A and 1-B through 6-B, respectively. The SAI II is scored by assigning point values to each of the attitude items. Scores for the various subscales can be determined by adding the scores for the respective items. Scores may be determined for the 12 subscales, a total for the positive items, a total for the negative items, and a total for the entire SAI II. The range of scores for each of the scales 1-A through 5-B is 3–15 (1–5 points X 3 items). The range of scores for scales 6A and 6B is 5–25 (1–5 points X 5 items). The range of scores for the entire SAI is 40–200 (1–5 points X 40 items).

Metacognitive Awareness

Metacognitive Activities Inventory (MAI). To measure the students’ metacognitive awareness, a metacognitive activities inventory (MAI) was used in this study. The Metacognitive Activities Inventory is a self-report developed by Schraw and Dennison (1994) that allows to measure adults’ metacognitive awareness. Items were classified into eight subcomponents subsumed under two broader categories: knowledge of cognition (metacognitive knowledge) and regulation of cognition (metacognitive skillfulness).

Results and Discussion

Status of Subjects Before Exposure to Metacognitive Activities

Every student who enters the portals of our classrooms brings with him or her preconceived notion about anything that is to be learned. They carry with them earlier experiences, understanding and misconceptions, feelings, and beliefs about the subjects to be learned and about themselves. Knowing these background knowledge and misconceptions is critical since they are usually enduring and difficult to purge (Arends and Kilcher, 2010). These factors along their personal perspectives of how well they would fare in the course may help or impede the level of engagements students are willing to take in the classroom. It is therefore imperative to find out the entry status of the subjects before the exposure to the intervention.

Affective Aspects of the Study: Motivation and Scientific Attitude

Earlier works on metacognition focused mainly on the role that metacognition in academic achievements. It is the contention of the present study that affective components play an integral role in making students thrive in Chemistry classrooms. For us to be effective facilitators of learning, knowledge of students drives and attitude towards Chemistry and science in general becomes imperative. The tables that follow show the affective components of the subjects based on the pretests.

### Table 1. Summary of Entry Level Motivation

| Subcomponent                          | Mean | SD    | Description | Rank |
|---------------------------------------|------|-------|-------------|------|
| Intrinsic                             | 3.862| 0.522 | Very High   | 1    |
| Self-determination                    | 3.523| 0.4994| Very High   | 2    |
| Extrinsic                             | 3.352| 0.6134| Very High   | 3    |
| Relevance to Personal Goals           | 3.271| 0.4994| Very High   | 4    |
| Anxiety about Science Assessment      | 3.052| 0.6310| High        | 5    |
| Self-efficacy                         | 3.033| 0.5707| High        | 6    |
| **Totality**                          | **3.3492**| **0.5607**| **Very High**|     |

The entry level motivation of the subjects is shown on Table 1. It can be noted that the subjects’ intrinsic motivation tops all the subcomponents. This means that Chemistry students entered into the classroom with “Very High” motivation to learn the course. One might wonder where this motivation is rooted when in fact as narrated earlier Chemistry is a difficult subject. Moreover, the entry chemistry competence is below average which therefore would have been symptomatic of a “poor motivation level”. One way to look at it is the innate desire of the students to able to demystify the puzzling nature of
macroscopic phenomena in the light of molecular or symbolic world. For instance, students are intrigued of these common observations: “sir unsa’y kalahan sa iron sa bike ug iron sa dugo?” [sir, what’s the difference between the iron found in our blood and the ironfound in the bicycle?], “kanang, nganu tay-un man ang putah sir, pero ang aluminum dili lagi? […]why does iron rust while aluminum doesn’t?”]. Questions like these provide some level of cognitive dissonance; hence, a higher level of intrinsic motivation. For classroom practice, this could mean that teachers should provide activities that highlight chemistry’s practical applications in understanding the “mysteries” of world they live in.

Meanwhile, as revealed in table 4, the subjects’ self-determination is “Very High”. The subjects are aware to some extent that there are factors both those that involve themselves and those that are external that cause their successes or failures in earlier chemistry experiences. These factors include ability, effort, luck, and difficulty of the learning task (Weiner,1972). Extrinsically, Table 4 shows that the subjects are “Very Highly Motivated”. Being a general education course, students do not necessarily feel that this subject is related in information technology program. This is even highlighted in the post interview script shown later. So what drives them to learn? Grades and graduation. After all, these two are the driving forces that propel them to enroll in the course. Many of the students are working scholars, food chain crew, and office staff. Therefore grades have to be maintained for them to stay as a scholar. Further, they feel that they have made big investment for the subject. It is therefore imperative to pass it or even earn a good mark.

In terms of relevance to personal goals, Table 4 reveals the subjects’ “Very High Motivation” entry level. This could be viewed that in general, learning chemistry has its practical purpose or significance in the lives of our students who enter our classrooms. However, anchoring chemistry in the purpose or goals of the program where the subjects are enrolled might prove to be slightly challenging. How to prepare classroom materials and raise the level of discussion in chemistry that is attuned to the personal goals of the students is a valuable consideration in Chemistry instruction.

On top of the students’ cause of anxiety are the chemistry examinations. This could be explained by the fact that results in examinations have implications not only in their social status in the class but also in the ultimate performance in the course. As presented, students are generally “Highly Motivated” consistent with other sub components in motivation. However; it is seen to be slightly lower in the spectrum. This means that while they have high confidence in learning chemistry lessons, assessment still creates a stigma among the students.

In all the motivation components, self-efficacy is relatively lower. Nonetheless, the subjects are still “highly motivated”. This could mean that students may feel relatively less confident that they will succeed in the class. This could be a good target behavior using the metacognitive activities as a tool to develop learners to take control of their own learning.

**Scientific Attitude Level Prior to the Intervention**

Attitude towards science or as used in this study, scientific attitude, can be defined as the feelings, beliefs, and values held about an object that may be the endeavor of science, school science, the impact of science and technology on society, or scientists (Ackay, Yager, Iskander, & Turgut, 2010, p1). The subjects’ attitude toward science may give us some insights and clues as to how students will fare in Chemistry instruction.

| Position Statement | Mean | SD  | Description    | Rank |
|--------------------|------|-----|----------------|------|
| **5AB** Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work. | 3.6310 | 0.6121 | Strongly Positive | 1 |
| **2AB** Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that. | 3.3532 | 0.4327 | Strongly Positive | 2 |
| **3AB** To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one’s position on the basis of sufficient evidence. | 3.3056 | 0.5086 | Strongly Positive | 3 |
**6AB** Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life’s work. I would like to do scientific work.

3.2214 0.5732 Strongly Positive 4

**1AB** The laws and/or theories of science are approximations of truth and are subject to change.

3.1984 0.3458 Strongly positive 5

**4AB** Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.

3.1587 0.4131 Moderately Positive 6

**Total**

3.3114 0.4809 Strongly Positive

Table 2 shows the subjects’ attitude towards science as determined by the position statements in the Scientific Attitude Inventory II (Moore & Foy, 1997) prior to their exposure to the intervention. Position statement 5AB “progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work” tops the rank and merit a “Strongly Positive” attitude from the subjects. It can be construed that the subjects strongly believed that the every citizen should understand science. This is expected because the subjects, being Information Technology students, are bombarded everyday by different technological advancement in the field of computer. Both the production of materials they use and themselves as co-creator of software and other related IT products and services expatiate science as a human enterprise. Settled at the bottom of the ranking; however, is position statement 4AB rendering it to be “Moderately Positive”. This finding could mean that subjects agree lightly (mean = 3.1587) on the attitude statements pertaining to science as an idea-generating activity and the nature of theoretical systems that operates in science. This could be because students who are entering in the chemistry course viewed highly the most practical contribution of science such as development of materials for modern infrastructure, technology, medicine, and other inventions of practical value to society. Just like many of us, the research subjects are consumers of knowledge and technology and often have less understanding or exposure to the creative inventions of theoretical systems that operates in the scientific endeavors. On the average the subjects showed a “Strongly Positive Attitude” towards science. This is expected because the subjects are bombarded by plethora of scientific materials, be it gadgets or news, environmental issues, pollution, health, advancement in military warfare, and space exploration. More so that they are information technology students, access to these materials is within the reach of their fingertips. In other words, science and its contribution to humanity has become part and parcel of our students’ collective consciousness thereby creating a good environment for the subjects to have “Strongly Positive” attitude towards science.

### Chemistry Performance Before the Intervention

Table 3. Subjects’ Entry Level Chemistry Performance

| Skills               | N  | Mean  | SD   | Description      | Rank |
|----------------------|----|-------|------|------------------|------|
| Periodic Table       | 42 | 2.381 | 1.652| Average          | 1    |
| Electronic Structure | 42 | 1.833 | 1.286| Average          | 2    |
| Formula Writing      | 42 | 1.405 | 1.083| Below Average    | 3    |
| Naming               | 42 | 1.095 | 1.031| Below Average    | 4    |
| Quantum Numbers      | 42 | 0.667 | 0.687| Poor             | 5    |
| Totality             | 42 | 1.4952| 0.7448| Below Average    |      |
Table 3 shows the subjects’ performance in the chemistry pretest. It can be gleaned that the students’ overall entry competence is below average (mean = 1.4952). Further, it showed that students struggled in quantum numbers but showed an average performance on items relating to periodic table and electronic structure, and “Below Average” for formula writing and Naming of inorganic compounds. Similar conceptual difficulties have been reported in earlier chemistry education researches (Maningo, 1999; Sirhan, 2007, Cardillini, 2012, Gafoor & Shilna, 2013). Students come to chemistry classrooms with conceptual difficulties. Students find it difficult to understand moles, atoms, quantum numbers (Maningo, 1999) periodic table and chemical bonding (Gafoor & Shilna, 2013) and related concepts that require a higher level of abstractions. The subjects’ entry level competence may provide us some clues into the nature of concepts the students mastered in high school chemistry. Where the difficulty lies and what this means to college chemistry teaching? Key in finding answer to these questions is the very nature of chemistry concepts. Chemistry exists in three forms: the macro and tangible that is, what can be seen, touched, and smelled; the submicro that includes atoms, molecules, ions, and structures; and the representational that involves symbols, formulae, equations, molarity, mathematical manipulations and graphs (Johnstone, 2000 & Chang, 2000). Students come to our classroom replete with experiences of the macroscopic world. What they see, touch, manipulate and feel. This makes chemistry as a course that we all can relate well. However, for chemistry phenomena and processes to be fully understood students have to be engaged with activities that reach the submicro and representational levels. In fact many observable phenomena that seem to be a mystery are ably understood and expounded at this level. Johnstone (2000) believes that this is the strength of chemistry as an intellectual pursuit but a task that proves to be challenging among students. Another reason for such dole performance could be the kind of learning experiences that students have engaged in earlier chemistry classes. Where the lessons taught in a way that the three touch points of macroscopic, submicroscopic, and representational levels are best addressed? Ali (2012) underscores the importance of students’ basic understanding of the learning situation, in this case, chemistry, because it may have direct effect coping with the advanced level knowledge. In this study, students wrote short essays on their earlier chemistry encounters. Although the students’ comments shown on the table below is not everything about their previous chemistry lessons, it gives an insights of students personal journey, struggles and triumphs of chemistry before entering our college chemistry classrooms. Laboratory activities that draws in curiosity and support to the abstract nature of the Chemistry, the teacher’s disposition and strategies of teaching are recurring themes that highlight the students earlier chemistry experience.

Another important consideration for the subjects’ dismal performance could be the time when the subjects have been exposed to Chemistry lessons. It is worthy to note that it was in their 3rd year in high school or roughly three years since that they took the Chemistry performance test. The subjects may have difficulty recalling the different concepts learned. With these insights; college instructors may provide innovative teaching strategies that would both help reignite students’ interest and at the same time present the subject cognizant of the touch points of chemistry learning presented.

**Metacognitive Awareness Before the Intervention**

One of the aims of this research endeavor is to assess the level of metacognitive awareness of the subjects prior to exposure to the metacognitive activities in chemistry instruction. One’s metacognitive level of awareness is divided into two areas: knowledge of cognition or metacognitive knowledge and regulation of cognition also known as metacognitive skillfulness. Metacognitive knowledge refers to the awareness of one’s thinking while metacognitive regulation is the ability to manage one’s own thinking processes (Darling-hammond, et al, 2003). Metacognitive knowledge that includes, declarative, procedural and conditional are found in table 2, while the five metacognitive skillfulness components, that is, planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation are presented on table 3. The sub skills or performance indicator for each sub component were removed for simplicity of discussion. It can be gleaned from the tables that students are “Excellant” on the average in both metacognitive knowledge and skillfulness; yet when this is juxtaposed with their dismal performance in Chemistry Pretest, there seems to be some cognitive incongruity. This tends to run against the grain of findings of earlier researchers as it will be discussed later that high metacognitive awareness are high predictors of academic success. One may think that students sporadically answer haphazardly the questionnaire; However, this could not be the case because accomplishing the pre-tests as well as posttests was thoroughly explained and monitored by the researcher. An earlier work may provide answer to this dilemma. Lovett’s (2008) earlier research on students’ metacognitive skills and beliefs provide enlightenment to the current finding. She found out that students tend to overestimate their abilities or become overconfident about what they can do. New strategies that fosters for self-regulating behavior are suggested to address both cognitive and affective concerns, that is, overconfidence. Another way to look at it is that, students have their personal
understandings of themselves, chemistry as a subject – ease or difficulty, and their “generic belief” about the use of strategies. This could mean that subjects enter the classroom loaded with their previous experiences, realizations, and insights that old routines may no longer work and as well as new (Dawson, 2008). This could mean that teachers can ably help students maximize this knowledge to achieve learning goals. Arends and Kilcher (2010) suggested that knowledge about the types of knowledge the students’ are well verse or oriented has instructional significance because it helps determine the type of teaching strategy for a particular lesson. A student who is “overconfident” may be given challenging tasks paired with activities that provide opportunities for reflection. On the other hand student who is visually oriented may use concept maps as a way to understand and remember important information, or a student who is not good in memorizing long lists of names may use mnemonics.

| Metacognitive Knowledge | N  | Mean  | SD   | Description | Rank |
|-------------------------|----|-------|------|-------------|------|
| Conditional             | 42 | 3.4849| 0.5668| Excellent   | 1    |
| Declarative             | 42 | 3.4179| 0.5832| Excellent   | 2.5  |
| Procedural              | 42 | 3.4179| 0.5668| Excellent   | 2.5  |
| Totality                | 42 | 3.4402| 0.5723| Excellent   |      |

Table 4 reveals the subjects metacognitive knowledge prior to the intervention. In general, the subjects who entered in the Chemistry classroom showed an “Excellent” metacognitive knowledge. This implies that our students come into our classrooms fully aware of what of their own capabilities and limitations. When accessed by the teacher, this information of students’ interest, motives, and pitfalls could be utilized in designing instructional activities that are cognizant of these realities. For example when the students are beset with the challenge in managing information and organizing data, teachers can ably infuse classroom activities that would target these skills alongside learning chemistry. In terms of procedural knowledge, the students are “Excellent”. This is expected because when the subjects come into chemistry classrooms, they have had problem-solving encounters. Hence they have a repertoire of learning strategies in earlier years of school in several subject areas. The automaticity in deploying these strategies though, “Excellent”, appears to be slightly lower. One reason could be that knowledge and dealing with problems is “conditionalized” (Bransford., Brown. & Cocking, 2000). This could explain, too, the disparity in the Chemistry performance and the metacognitive awareness. Using a strategy requires context, specificity, and applicability. The students may show excellent knowledge and skills in programming or mathematics subjects, for example, but may find it challenging to solve things in Chemistry activities. One imperative in our teaching learning activities; therefore, is to allocate time for formative activities that fosters the development of these skills among our learners. Table 4 further shows that the subjects have “Excellent’ conditional knowledge. This means that they learn best when they have full grasp of the topic to be learned and tasked to be accomplished. Essential to the success in chemistry lessons and beyond is the subjects’ ability to use the appropriate declarative and procedural knowledge in different chemistry tasks. This means that it is not enough that students acquire knowledge; knowing when and where to use it to achieve one’s ends are equally important (Turns and Van Meter, 2011).

| Metacognitive Skillfulness | N  | Mean  | SD   | Description | Rank |
|----------------------------|----|-------|------|-------------|------|
| Planning                   | 42 | 3.5748| 0.5762| Excellent   | 1    |
| Debugging                  | 42 | 3.4961| 0.4559| Excellent   | 2    |
| Evaluation                 | 42 | 3.4747| 0.4636| Excellent   | 3    |
| Strategy                   | 42 | 3.4522| 0.4776| Excellent   | 4.5  |
| Monitoring                 | 4  | 3.4522| 0.4775| Excellent   | 4.5  |
| Totality                   | 42 | 3.4874| 0.4084| Excellent   |      |
As a whole, the entry level metacognitive skillfulness of the subjects is “Excellent”. Top on the rank is the students’ planning skills with a mean, followed by the debugging, evaluation, and lastly strategy and monitoring. A detailed analysis and discussion on the metacognitive knowledge and skillfulness will be devoted in the contrasting of pretest and posttests.

Integration of Metacognitive Activities in Chemistry Instruction

The metacognitive activities were integrated in the teaching learning activities (TLAs) in the Chemistry 1 lessons. Figure 3 shows a simplified three-step flow of Chemistry instruction integrating these activities.

**Step 1** is **preparation** which intended to prepare the class for the integration. It involves assessing the students’ learning status which will be of great help in the creation of learning teams, and then students took the pretests. This was followed by mini-training on metacognition and self-regulated learning. In the present study, the students developed their own Cornell notes from recycled papers. Rubrics for assessing the quality of products were also presented and negotiated in the class. After seeking for clarifications the class was ready by this time for the integration proper. In **step 2, integration**, the students faced two instructional tasks: a) cognitive tasks which refer to the different chemistry activities like electronic structure, quantum numbers, periodic table, formula writing, and naming compounds; b) metacognitive tasks that include learning portfolio, metacognitive discussion, assignment wrapper, session reflection log, goal-setting, and learning community. **Step 3**, is the checking on the effectiveness of the chemistry instruction. This stage, **evaluation**, requires observations of behavior changes in the subjects: the cognitive, affective, and metacognitive effects referred to as the center piece problem of the current research endeavor. This was done by providing different assessment tasks like written self-assessment, interviews, and products. The teacher also contrasted the pretest and posttest results to see significant improvements in the subjects’ status. The findings and there implications will facilitate teachers and instruction implementers to feed forward for an improved chemistry instruction. In this framework, skills or conceptual development in Chemistry are achieved alongside the different metacognitive tasks. **Figure 4**, shows the constructive alignment of teaching learning activities (TLAs), intended learning outcomes (ILOs), and assessment tasks (ATs) that served as the guide posts in skill development. At the heart of metacognitive instruction is how students are guided to achieve the target skill from smaller progressions of sub skills. This learning progression model which was anchored from the work of Popham (2008) as quoted by Arends and Kilcher (2010), shows the iterative process in developing the targeted skill and the role of formative assessments and feedback as an indispensable tool for both cognitive and metacognitive development. The targeted skill is developed in smaller progression or development of the essential sub skills. The development of this skills is deeply rooted in the

**Figure 3. Implementation Flow of Metacognitive Activities**

### Impact Factor:

| Journal          | Impact Factor |
|------------------|---------------|
| ISRA (India)     | 4.971         |
| ISI (Dubai, UAE) | 1.582         |
| GIF (Australia)  | 0.564         |
| JIF             | 1.500         |
| SIS (USA)        | 0.912         |
| ICF (Poland)     | 6.630         |
| PIII (Russia)    | 0.126         |
| ESJI (KZ)        | 9.035         |
| IBI (India)      | 4.260         |
| SJIF (Morocco)   | 7.184         |
| OAJI (USA)       | 0.350         |

Philadelphia, USA

9
interwoven cognitive, in particular, the Chemistry tasks, with the different metacognitive tasks. Ultimately, the students’ competence is primarily a function of both their ability to handle Chemistry lessons (cognitive) and planning, monitoring, and evaluating skills through the seven metacognitive activities (metacognitive tasks). The students’ exit skills are assessed if the intended learning outcomes are achieved; thus providing feedback to the effectiveness to whole instructional design.

The Metacognitive Activities
This study attempted to find out how classroom processes can be structured so that activities that foster metacognitive awareness can be infused in Chemistry instruction. As suggested by Weisler and Meyer (Cornford, 2002) there are two ways in which metacognition can be taught. First, metacognition can be integrated in our curriculum using adjunct approach in which case, a parallel training to develop metacognition is given to the students outside a certain subject. The second way is through a metacurricular approach. In this case, metacognitive activities that promotes students metacognitive skillfulness is integrated in a specific content subject. The present research undertaking used primarily the metacurricular approach both for practical (adding another mini-class for metacognition would entail time and resources for both the teachers and the students which make it improbable to use with the current school set-up) and pedagogical reasons. These metacognitive activities formed part of what the researcher will term as metacognitive tasks (MT). Rather than an add-on activity, researcher infused the MTs with the Cognitive Tasks (CT) that is, activities inherent to Chemistry. However, an adjunct teaching will be used to make explicit and overt the cognitive and metacognitive strategies which had been taught but embedded in the subject content. Lin (2001) and Cornford (2002) support this holistic approach. They contend that activities should be an integrated, natural part of the learning process rather than an add-on procedure. As commented by Louca (2008) on her review of the works of Vygotsky’s Social Cognitive Development; “learning to learn does not happen in a vacuum, it must be in a context of certain content”. This is supported by earlier works in the field of science education that infused metacognitive activities alongside the content (Lovett, 2008). Metacognitive Skills are be developed or learned along with Chemistry topics. To achieve this, the researcher chose seven (7) metacognitive activities intended to foster metacognitive skillfulness among chemistry students. Each of the metacognitive activity is intended to explicitly teach students’ metacognitive strategies and collectively build a classroom culture conducive for metacognitive development. There are seven metacognitive activities that will be utilized in the present research undertaking, viz: 1) Learning Impact Factor:

| Journal | Impact Factor |
|---------|-------------|
| ISRA (India) | 4.971 |
| ISI (Dubai, UAE) | 1.582 |
| GIF (Australia) | 0.564 |
| JIF | 1.500 |
| SIS (USA) | 0.912 |
| PIII (Russia) | 0.126 |
| ESJI (KZ) | 9.035 |
| IBI (India) | 4.260 |
| SJIF (Morocco) | 7.184 |
| OAJI (USA) | 0.350 |

Portfolios (LP), 2) Metacognitive Planning/Feedback/Discussion 3) Metacognitive Wrapper, 4) Session Reflection Log, 5) Goal-setting, 6) Metacognitive Note-taking and 7) Learning Community. The activities correspond to specific episodes of the instructional cycles and were tweaked with the intent of purposefully helping students develop metacognitive awareness.

The discussion here is a humble attempt to narrate how these activities were implemented in the chemistry instruction adhering as much as possible to the guidelines set forth at the outset of the study. A short description about the activity as well as snippets of classroom events where these activities were used in the chemistry classrooms are hereby included. Students’ brief accounts on these activities are also provided to flesh insights into the students’ deeper thoughts regarding the MTs.

Learning Portfolio

Learning portfolio served as a repository of students output. It contained course outline in chemistry, conversion table, periodic table, student individual action plan, reflection log, goal-setting sheets, monitoring chart, student individual performance record (scores on quiz, seatwork, attendance, self-rated oral recitation), and different outputs from chemistry activities. The plan to give the students with a softcopy of an excel files with formula for grade computation for those who wish to make a personal assessment of their grades did not push through. Given the bulk of loads the students have in chemistry and other subjects, the researcher deemed it tedious in the part of the students to still go through the excel-grading activity. Students bring the portfolio every class period since all the materials for purposes already discussed. There were instances when some students forgot to bring their portfolio, they were not reprimanded but they were asked by the teacher to explain their side. Some students found the portfolio heavy and taxing to bring, while others found it useful as a repository of “items” not only in chemistry but also in other subjects. So why would the students bring the portfolio? It was ensured that every class period the materials found in the portfolio were used in the daily activities; hence; providing a natural motivation to bring it. One of the highlights in this activity was the use of daily class record, specifically, the personal oral recitations. Students were excited to record the rating they gave to themselves. Although, these ratings did not have a bearing on their grades, the researcher believes that it is a form of reflection that is instrumental for adaptive metacognition (Lin, Schwartz, & Hatano, 2005). Since the portfolio provides evidence symptomatic of the students’ cognitive and metacognitive developments, it was assessed on the basis of completeness and quality of output. The portfolios were checked three times during the duration of the study. A detailed discussion of some portfolios will be dealt in details during the discussion of sample subject cases.

Metacognitive Planning/Feedback/Discussion

This activity allowed students to engage in the class-wide discussions concerning “understandings” or doubts, queries or problems they encounter as they wade through the different topics in chemistry class. While feedback and whole-class discussion were done in any part of the lesson, it was observed to be strategic at key phases of the instructional cycles. Used during the pre-lesson or lesson introduction, this activity served as a planning scaffolds. It was an important tool in tapping students’ prior knowledge. It was also used during the lesson proper as a monitoring tool on learning check points. During the post lesson, this activity was used as “stabilizing” mechanism to galvanize students’ understanding of the lesson.

Status of Subjects After Exposure to Metacognitive Activities

Affective Components After Exposure to the Metacognitive Activities

One of the ends of this research is to find out the affective effects of the seven metacognitive activities. Table 6 and 7 reveal the posttest results of the subjects’ motivation and scientific attitude, respectively.

Table 6. Post Intervention Motivation Level

| Subcomponent                        | N  | Mean | SD  | Description | Rank |
|-------------------------------------|----|------|-----|-------------|------|
| Intrinsic                           | 42 | 3.870| 0.680| Very High   | 1    |
| Extrinsic                           | 42 | 3.7479| 0.6199| Very High   | 2    |
| Relevance to Personal Goals         | 42 | 3.6232| 0.6026| Very High   | 3    |
| Self-determination                  | 42 | 3.6006| 0.667| Very High   | 4    |
| Self-efficacy                       | 42 | 3.5216| 0.5669| Very High   | 5    |
| Anxiety about Science Assessment    | 42 | 3.4063| 0.4723| Very High   | 6    |
| Total                               | 42 | 3.6283| 0.601| Very High   |      |
Table 6 shows that the subjects’ level of motivation have improved in all subcomponents to be “Very High”. Whether there is a significant improvement in the subcomponents or as a whole, it will be determined after the pre-posttest results are contrasted. Meanwhile, the intrinsic motivation still remains to be the top factor for motivation of the students. Although, a marked improvement was seen in both self-determination and anxiety about science, the two subcomponents slid slightly in the ranking. One reason for this is the significant improvements the subcomponents “in relevance to personal goals” and “self-efficacy as will be discussed later.”

### Scientific Attitude after the Intervention

| Position Statement                                                                 | Mean  | SD    | Description      | Rank |
|----------------------------------------------------------------------------------|-------|-------|------------------|------|
| 3AB To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one’s position on the basis of sufficient evidence. | 3.3916 | 0.3834 | Strongly Positive | 1    |
| 5AB Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work. | 3.3518 | 0.3063 | Strongly Positive | 2    |
| 4AB Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects. | 3.3292 | 0.3063 | Strongly positive | 3    |
| 1AB The laws and/or theories of science are approximations of truth and are subject to change. | 3.3254 | 0.3789 | Strongly Positive | 4    |
| 6AB Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life’s work. I would like to do scientific work. | 3.2873 | 0.3252 | Strongly positive | 5    |
| 2AB Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that. | 3.2817 | 0.3642 | Strongly Positive | 6    |

The post intervention scientific attitude of the students toward science as shown on Table 7, is “Strongly Positive”. On average, the subjects’ attitude showed a very small increment in the different positions statements. First in the rank is the position statement **3AB**: To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one’s position on the basis of sufficient evidence. The “Strong Positive” attitude shown by the subjects toward this statement is expected because they have been witnesses to social and technological ramifications breakthroughs bought about by these technological breakthroughs. This could mean too that subjects have high regard to scientists as to the veracity of their claims and confident that the processes are done judiciously. In the contrary **2AB**, tail ended in the spectrum with a mean of 3.2817, although this is still “Strongly Positive” attitude. This could mean that students view science and scientist cannot provide answers to all our questions.
Table 8. Chemistry Performance

| Skills              | N  | Mean  | SD   | Rank | Description | Rank |
|---------------------|----|-------|------|------|-------------|------|
| Periodic Table      | 42 | 4.286 | 1.785| 1    | Excellent   | 1    |
| Electronic Structure| 42 | 3.718 | 1.270| 2    | Excellent   | 2    |
| Formula Writing     | 42 | 3.381 | 1.378| 3    | Excellent   | 3    |
| Naming              | 42 | 3.214 | 1.554| 4    | Excellent   | 4    |
| Quantum Numbers     | 42 | 1.619 | 0.936| 5    | Average     | 5    |
| Totality            | 42 | 3.2476| 0.9008|      | Excellent   |      |

Table 8 shows the subjects Chemistry performance after exposure to the metacognitive activities. It can be gleaned from the table that the overall performance is “Excellent”. Their performance is “Excellent”, too, in four sub concepts considered, namely, periodic table, electronic structure, and formula writing, and naming of inorganic compounds. However, although there was an improvement in terms of performance, that is, from “Below Average” or “Average to “Excellent”, students level of difficulty in terms of the sub concept considered remain the same. Table 9 shows the comparison of ranking between the pretest and posttest in Chemistry performance. It is very interesting that in this study, the periodic table tops the students’ performance, while in earlier research, usually this is considered by many students as the most difficult conceptual hurdle (Gafoor and Shilna, 2013).

Table 9. Subjects’ Pretest and Posttest Results in Chemistry

| Skills/Concepts    | Pretest |               |         |         |               |         |
|--------------------|---------|---------------|---------|---------|---------------|---------|
|                    | Mean    | Description   | Rank    | Mean    | Description   | Rank    |
| Periodic Table     | 2.381   | Average       | 1       | 4.286   | Excellent     | 1       |
| Electronic Structure| 1.833   | Average       | 2       | 3.718   | Excellent     | 2       |
| Formula Writing    | 1.405   | Below Average | 3       | 3.381   | Excellent     | 3       |
| Naming             | 1.095   | Below Average | 4       | 3.214   | Excellent     | 4       |
| Quantum Numbers    | 0.667   | Poor          | 5       | 1.619   | Average       | 5       |
| Totality           | 1.4952  | Below Average |         | 3.2476  | Excellent     |         |

When compared to the work of Gafoor and Shilna (2013), periodic table, followed by chemical bonding, world of carbon was regarded as the most difficult concepts. However, looking into other concepts in their study indicated that in fact, these topics are relatively the most abstract and symbolic in nature compared to topics on mixture and nature of substances considered in their work. In essence the present study and their work draw the parallel experience that the difficulty is also a function of the Chemistry triangle proposed by Johnstone (2000). Maningo (1999) also found out similar observations. Although there were significant improvements in the subjects’ performance using limericks, a chemistry-manipulation device, generally, the difficulty according to topics remain the same. However, among the most abstract topics, it is surprising that electronic structure which usually reported to be the most difficult to comprehend because of its very abstract nature, subjects in this research showed to have learned this concept well. When asked for reasons, student appreciated the use of “hotel analogies” used in this study and their personal analogies like “ang energy levels and orbitals kay mura’g data folders man sab na sya sir. Nau sya’s murm sequence-sequence”. In effect, even the most abstract material can be understood by providing students with opportunity to grasp the concepts using similarities in the actual and more tangible world. The effectiveness of this strategy was also observed in other classroom settings where doing experimentation or physically observing the phenomena is not possible (Ali, 2012). Ali (2012), however, contend that though these models, analogies and imageries may help in the in facilitating learning topics such as atomic models, they may not provide sufficient conditions to help
develop conceptual understanding of the topic. It is therefore imperative for teachers to emphasize that these symbols, formulae or models are representations of different properties of substance and not a copy of anything (Treagust, Duit & Niewswandt, 2000). Hence, in this research, classroom learning teams and discussions and feedback were used to support this end.

| Table 10. Subjects’ Post-Intervention Metacognitive Knowledge |
|-------------------------------------------------------------|
| **Metacognitive Knowledge**                              | **N** | **Mean** | **SD** | **Description** | **Rank** |
| Conditional                                               | 42    | 3.6810   | 0.5726 | Excellent       | 1        |
| Procedural                                                | 42    | 3.5833   | 0.5729 | Excellent       | 2        |
| Declarative                                               | 42    | 3.5506   | 0.4357 | Excellent       | 3        |
| Totality                                                  | 42    | 3.6049   | 0.527  | Excellent       |          |

The post-intervention metacognitive knowledge of the subjects is shown in Table 10. On average they have an “Excellent” metacognitive knowledge just like the pretest. Conditional knowledge ranked first with a mean of 3.6 followed by procedural and declarative with means of 3.5833 and 3.5506, respectively. There is a slight increment in the means of the three metacognitive components. This means that the metacognitive activities may have helped in the students’ ability to be aware of factors and conditions related to self and the course as they learn Chemistry.

| Table 11. Post-Intervention Metacognitive Skillfulness |
|-------------------------------------------------------|
| **Metacognitive Knowledge**                           | **N** | **Mean** | **SD** | **Description** | **Rank** |
| Debugging                                              | 42    | 3.8905   | 0.5963 | Excellent       | 1        |
| Planning                                               | 42    | 3.7449   | 0.5771 | Excellent       | 2        |
| Evaluation                                             | 42    | 3.5516   | 3.4747 | Excellent       | 3        |
| Strategy                                               | 42    | 3.4976   | 0.5771 | Excellent       | 4        |
| Monitoring                                             | 42    | 3.4762   | 0.4813 | Excellent       | 5        |
| Totality                                               | 42    | 3.6049   | 0.527  | Excellent       |          |

The other component of metacognitive awareness is the metacognitive skillfulness. This component involves planning strategy, monitoring, debugging, and evaluation (Schraw and Dennison, 1994). Table 11 shows that, debugging and planning topped the post-intervention metacognitive skillfulness of the group. It can be gleaned from the table that there were slight increments in all the areas considered. The subjects’ average metacognitive skillfulness was “Excellent” after the intervention.

| Table 12. Pretest and Posttest Results for Motivation |
|------------------------------------------------------|
| **Sub component** | **Pre-test** | **Posttest** | **Diff** | **T-Value** | **P- Value** | **Description** |
|               | **Mean** | **SD** | **Mean** | **SD** |          |            |                |
| Intrinsic     | 3.862   | 0.522 | 3.870   | 0.680 | 0.008    | 0.07       | 0.945          | Not Significant |
| Extrinsic     | 3.3524  | 0.6134| 3.7479  | 0.6199| 0.396    | 3.49       | 0.001          | Significant     |
| Relevance to Personal Goal                           | 3.2714  | 0.4994| 3.6232  | 0.6026| 0.352    | 3.14       | 0.003          | Significant     |
| Self- determination                                  | 3.5238  | 0.5281| 3.6006  | 0.667 | 0.77     | 0.75       | 0.460          | Not Significant |
| Self-efficacy                                        | 3.0333  | 0.5707| 3.5216  | 0.5669| 0.488    | 3.94       | 0.000          | Significant     |
ISRA (India) = 4.971  SIS (USA) = 0.912  ICV (Poland) = 6.630
ISI (Dubai, UAE) = 1.582  PIM (Russia) = 0.126  PIF (India) = 1.940
GIF (Australia) = 0.564  ESJ (KZ) = 9.035  IBJ (India) = 4.260
JIF = 1.500  SJIF (Morocco) = 7.184  OAJI (USA) = 0.350

| Anxiety about Science Assessment | 3.0524 | 0.6310 | 3.4063 | 0.4723 | 0.354 | 2.96 | 0.005 | Significant |
|----------------------------------|--------|--------|--------|--------|-------|------|-------|-------------|
| Totality                         | 3.3492 | 0.5607 | 3.6283 | 0.601  | 0.2791| 2.39 | 0.000 | Significant|

* $P < 0.05$

Table 12 reveals that contrasted pretest and posttest motivational level of the subjects. It can be gleaned from the table that there was an overall significant improvement of the students’ motivation when exposed to the different metacognitive activities. Hence, the null hypothesis on this parameter is rejected. Four subcomponents, namely, extrinsic, relevance to personal goals, self-efficacy, and anxiety about science or Chemistry assessment, have shown a significant improvements with P value lesser than 0.05. The other two subcomponents, though, they have shown an increment, did not warrant significant improvement after the exposure. This could be because students have already considered themselves “Highly Motivated” in those areas at the beginning of the study. A closer look and discussion into these components is in place.

| Position Statements | Pre-test | Posttest |
|---------------------|----------|----------|
|                     | Mean     | SD       | Mean     | SD       | Diff     | T-Value | P-Value | Description |
| 1-AB                | 3.1984   | 0.3458   | 3.3254   | 0.3789   | 0.1270   | 1.86    | 0.069   | Not Significant |
| 2-AB                | 3.3532   | 0.4327   | 3.2817   | 0.3642   | 0.0714   | 0.4100  | 0.265   | Not Significant |
| 3-AB                | 3.3056   | 0.5086   | 3.3916   | 0.3834   | 0.0860   | 0.99    | 0.326   | Not Significant |
| 4-AB                | 3.1587   | 0.4131   | 3.3292   | 0.3153   | 0.1705   | 0.4586  | 0.021   | Significant |
| 5-AB                | 3.6310   | 0.6121   | 3.3518   | 0.3063   | 0.2792   | 3.32    | 0.002   | Significant |
| 6-AB                | 3.2214   | 0.5732   | 3.2873   | 0.3252   | 0.0659   | 0.89    | 0.380   | Not Significant |
| Totality            | 3.3114   | 0.4809   | 3.3278   | 0.3906   | 0.0164   | 1.321   | 0.177   | Not Significant |

* $P < 0.05$

Subjects in the present study; however, tend to disagree with this result. While metacognitive activities made them reflect which is essential in any self-regulating tasks, they suggested that laboratory and relevant hands-on activities may provide opportunities for students to experience how scientists do science. The present study suggests that when instruction is fortified with activities that targets metacognitive skillfulness coupled with laboratory tasks that resemble the works of men of science, then attractiveness of science among our students may render a stronger pull in the hearts of our students.

One interesting question though that lingers is what could account for students significant improvement in position 4A (P value = 0.021) and the significant decline in position statement 5AB (P value = 0.002).

Significant improvement in Students’ Attitude with regards to position statement 4AB:
Position Statement 4AB

“Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects”

One reason could be that the metacognitive activities did not only allow for a generic reflection of how their thinking processes; it also afforded them thinking processes that are inherent to developing hypothesis and theoretical systems. It is in these theoretical systems that scientists explain the world we live in. As Lawson (1995) puts it: “scientific knowledge is a product of human mental construction...” This of course necessitates reflective components of self-regulation. Thus when subjects in this research look into where the difficulty lies and what models or diagrams can be made to simplify the
concept they are learning, making sense of the explicit and implied patterns in periodic tables, and in devising better strategy for naming and formula writing; in effect they are exercising the creative and critical thinking process that are required of scientists to explain the different phenomena in nature. This could be the key why students after going through the different activities improved significantly in their appreciation of the theoretical aspects of science.

**Observed Decline in Students Attitude with regards to position statement 5AB:**

*Position Statement 5AB:

“Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.”*

It should be underscored here that science attitude for statement 5AB in posttest mean (M = 3.3518) is still “Strongly Positive” despite the decline. This could be interpreted that in fact students remained strongly supportive on position statements in the questionnaire that include: “most people can understand science”, “people must understand science because it affects their lives”, “every citizen should understand science”, and opposed position statements such as: “only highly trained scientists can understand science”, “most people are not able to understand science”, “scientific work is useful only to scientists”. The decline could be accounted well when it is viewed from the perspective of the subjects as consumer of scientific products, that is, knowledge to expound several questions about nature, technology that provides connectivity, comfort or perhaps processes and procedures that saves lives. This seems to be counterintuitive since, these scientific outputs with all its benefits and advantages are supposed to draw science closer to people. However, in the context of the position statement 5AB, one may use any of the aforesaid scientific advancement without having to go through the mental rigor associated in discovering them. A student may use an atm machine and appreciates the convenience he enjoys without knowing the actual mechanism that operates it. It is the same with Positron Emission Technology (PET) or Computerized Tomography Scanning (CT-Scan), used in modern hospitals. These technologies allow views on the internal organs for diagnostic and other medical purposes; but patients or medical practitioners would never care the minutiae of these technologies. In the context of the Chemistry lessons, it can be argued that, students after going through the mental processes cited in an earlier discussion in the discussion on “significant improvement in Students attitude with regards to position statement 4AB” may have realized that indeed Chemistry, like any other sciences, has its own unique set of requirements in terms of thinking processes and skill that will allow individuals to participate in scientific endeavors. This provides the rationale for the decline observed in the attitudes of the subjects with respect to position statement 5AB.

### Table 14. Pretest and Posttest Chemistry Performance

|                  | N  | Mean | SD  | T-Value | P-Value | Description  |
|------------------|----|------|-----|---------|---------|--------------|
| Pre-Test         | 42 | 7.476| 3.724| 10.69   | 0.000   | * Significant|
| Post Test        | 42 | 16.238| 4.504|         |         |              |
| Difference       | 42 | 8.762| 5.314|         |         |              |

Table 14 and earlier at Table 9, show how the subjects fared in the chemistry performance test in both the pretest and posttest. It can be gleaned from tables that subjects were below average during the pre-test and are excellent during the posttest. At p value =0.000 at .05 significance, there is a significant mean gain in terms of performance. This means that after going through the different metacognitive activities as they learned Chemistry concepts, the subjects have shown a marked improvement in the course. This finding supports earlier claims that metacognition has significant role in teaching and learning Chemistry and other sciences in general (Rickey & Stacy, 2000; Peklaj, 2001; Pulmones, 2007; Lovett, 2008, Nhin, J. B., &Viko, B., 2010; Tanner, 2012). Developing metacognitive skillfulness among students could greatly help students learn how to use their content knowledge more appropriately and flexibly Rickey and Stacy (2000). To do this, the use of instructional strategies like the ones used in the present research must be taught alongside the content. These activities may include, concept maps, concept tests, predict-observe-explain tasks (Rickey and Stacy, 2000), metacognitive wrappers (Lovett, 2008). Pulmones (2007), found out that when students were engaged in chemistry activities designed in a metacognitive environment, they had the ample opportunities to demonstrate planning, monitoring, and evaluation skills. These skills, with debugging and use of strategy together
with the different metacognitive knowledge form one’s metacognitive awareness. Rahman and Jumani (2010) reported that highly metacognitive aware students performed better on Chemistry tests than their low metacognitively aware counterparts.

In fact even researches in other field draw parallel findings that students who are strongly metacognitive, that is, self-regulated, who excel in planning, managing information, monitoring, debugging and evaluating are more successful learners (Tok, Ozgan, Dos, 2010; Sawney & Bansal, 2015). It is justifiable, therefore, to deduce that the metacognitive activities integrated in the different chemistry lessons drew some positive effects in the students’ performance. Thus, the null hypothesis on Chemistry performance as parameter is rejected.

**Contrasting Pretest and Posttest Metacognitive Awareness**

### Table 15. Pretest and Posttest Results for Metacognitive Knowledge

| Metacognitive Knowledge | Pre-test | Posttest | Diff | T-Value | P-Value | Description |
|-------------------------|----------|----------|------|---------|---------|-------------|
|                         | Mean     | SD       | Mean | SD      |         |             |
| Declarative Knowledge   | 3.4179   | 0.5832   | 3.5506| 0.4357  | 0.133   | 1.20        | 0.235       | Not Significant |
| Procedural Knowledge    | 3.4179   | 0.5668   | 3.5833| 0.5729  | 0.165   | 1.43        | 0.162       | Not Significant |
| Conditional Knowledge   | 3.4179   | 0.5668   | 3.6810| 0.5726  | 0.1961  | 2.03        | 0.049       | Significant    |
| Totality                | 3.4402   | 0.5723   | 3.6049| 0.5726  | 0.1647  | 1.553       | 0.149       | Not Significant |

*P < 0.05

Table 15 shows the pre-post results of the subjects’ metacognitive Knowledge. While there is slight improvements in the different subcomponents only the change in conditional knowledge is significant at P value = 0.049. This finding confirms Schunk’s (2012) assertions that conditional knowledge is independent from both declarative and procedural knowledge. In the context of the present study, the subjects did not only show some level of mastery of Chemistry concepts, but also the appropriateness of learning strategies called for. Students’ reported their thinking process during the interviews: “kung dili mi kahibaw kay mu ask me sa amo grupo” [if we don’t know we ask help from our group mates] “mag net me sir usually… dugay man gud sa library mas paspas sa net” [we usually surf the internet… because it’s faster using the net than readings books in the library], “Mangutana me sir, sa kung kanus-a gamiton at “ite” “rate” ugu “ide” [we ask from the group members when to use the “ite, “ate”, and “ide”]; “I think, nindot nga hotel analogies kay ma visualize nimu ang problem regarding sa atoms” [I think the use of hotel analogy is helpful. You can really visualize the problems on atoms]. In can be noticed that, students’ comments draw a parallel skills in the part of debugging which is defined as the students ability to apply strategies used to correct understanding and actions in the process of completing a task. As shown on table 16, debugging as a subcomponent of metacognitive skillfulness marked a significant improvement with a P value of 0.466.

### Table 16. Pretest and Posttest Results for Metacognitive Skillfulness

| Metacognitive Skillfulness | Pre-test | Posttest | Diff | T-Value | P-Value | Description |
|----------------------------|----------|----------|------|---------|---------|-------------|
|                            | Mean     | SD       | Mean | SD      |         |             |
| Planning                   | 3.5748   | 0.5762   | 3.7449| 0.5771  | 0.1701  | 1.70        | 0.096       | Not Significant |
| Strategy                   | 3.4522   | 0.4776   | 3.4976| 0.5130  | 0.0454  | 0.47        | 0.638       | Not Significant |
| Monitoring                 | 3.4392   | 0.4775   | 3.4762| 0.4813  | 0.0370  | 0.41        | 0.684       | Not Significant |
| Debugging                  | 3.4961   | 0.4559   | 3.8905| 0.5963  | 0.394   | 3.95        | 0.000       | Significant    |

Philadelphia, USA

17
This means that students are able to address questions such as: “I ask others for help when I don’t understand something”, “Change strategies when I fail to understand”, “Re-evaluate my assumptions when I get confused”. Apparently, the same questions are addressed while the students are trying to address the conditions upon which they could ensure successful performance in Chemistry class activities. This relationship of the two subcomponent skills lends answer to the significant improvement observed.

On the average; however, both knowledge and regulation of cognition of the subjects did not show any significant improvements after the intervention. Hence, the null hypothesis on this parameter that there is no significant improvement in the metacognitive awareness is hereby accepted. One reason that is at play in this research is the time of exposure. Perhaps when students are exposed to longer period of time then significant improvement may be seen on all the different subcomponents. As Schunk (2012) pointed out, metacognition develops slowly. Teachers may provide longer exposure to students in the different activities. Further, collaboration could be done among faculty members in different subjects where the students are enrolled so there could be a more comprehensive metacognitive exposure beyond Chemistry classrooms. Another interesting angle to explore is the role of students’ belief on one’s competence before the actual Chemistry activities than the actual conduct. If it were the case, then this finding lends support to our earlier assumptions that students may have overestimated their abilities at the outset of the study. Earlier work echoes the same observation. While assessing students metacognitive awareness during problem-solving in kinetics and homogeneous design course, Ramirez-Corona, Zaira, López-Malo, & Palau (2013) argued that the same reasoning when a subject showed a decrease in its metacognitive awareness score, “we think that he over-assessed its metacognitive awareness in the pre-test and after a whole semester of practicing, recognized its limitations regarding his metacognition skills” (p.9). Students in this situations may have gained a more accurate understanding of themselves, thus, some students may show an increase while others a decrease in the metacognitive awareness scores. Prudence must therefore be taken when conducting researches that rely solely on self-report on metacognition since the subjects may not be able or are not willing to report accurate judgment (Hargrove, 2015).

The Cognitive Effects of Metacognitive Activities

| Metacognitive Activities       | Frequency | %    | Rank |
|--------------------------------|-----------|------|------|
| Learning Community             | 13        | 30.95| 1    |
| Discussion/feedback            | 10        | 23.81| 2    |
| Learning Portfolio             | 9         | 21.42| 3    |
| Cornell Notes                  | 6         | 14.29| 4    |
| Goal Setting                   | 2         | 4.76 | 5    |
| Wrapper                        | 1         | 2.38 | 6.5  |
| Session Reflection Log         | 1         | 2.38 | 6.5  |
| **Totality**                   | **42**    | **100** |     |

Table 17 shows the ranking of the different metacognitive activities as to the felt effectiveness by the students. Thirteen or 30.95 % of the total students rated learning teams as the activity that help them learn in the chemistry lessons. Discussion and learning portfolio at rank 2 and 3 respectively. Wrapper and session reflection log tied at the bottom of the rank. The effectiveness of group and collaborative strategies has been explored in earlier works. Johnson and colleagues (2008) as cited by Brame (2015) contend that many instructors use small groups or peer-to-peer instruction to promote students working together to maximize their own and each other’s learning. The purpose could vary from increasing student understanding of content, to build particular transferable skills, or some combination of the two. In other words, when the class of 42 students was divided into mini-chemistry classes everyone was given the chance to participate. An opportunity which is often times not afforded to all due to class size and instructional time constraints. Further, students who
Table 18. Ranking of Metacognitive Activities as to their effectiveness in making students become more motivated in chemistry class.

| Metacognitive Activities    | Frequency | %    | Rank |
|-----------------------------|-----------|------|------|
| Learning Community          | 17        | 40.48| 1    |
| Discussion                  | 11        | 26.19| 2    |
| Cornell Notes               | 9         | 21.43| 3    |
| Wrapper                     | 2         | 4.76 | 4.5  |
| Goal Setting                | 2         | 4.76 | 4.5  |
| Learning Portfolio          | 1         | 2.38 | 6    |
| Session Reflection Log      | 0         | 0    | 7    |
| **Totality**                | **42**    | **100**|      |

Table 18 reveals that subjects regarded learning community as the metacognitive activity that made them feel motivated in chemistry class. There were 17 (40.48%) of the participants that ranked it first. It was followed by discussion/feedback which was chosen by 11 students (26.19%) and Cornell notes with nine (21.43%) students. Wrapping and goal setting are tied at ranked 4.5 with both chosen by two (4.76%) students. Meanwhile learning portfolio and session reflection log were posted at the bottom of the rank. The context of the ranking can be understood fully by listening to the voices of the students themselves.

**Students’ Scientific Attitude**

Table 19. Ranking of Metacognitive Activities in terms of effectiveness in making students feel like a scientist while in Chemistry 1 class.

| Metacognitive Activities       | Frequency | %    | Rank |
|--------------------------------|-----------|------|------|
| Discussion/Feedback            | 15        | 35.71| 1    |
| Goal Setting                   | 7         | 16.67| 2.5  |
| Learning Community             | 7         | 16.67| 2.5  |
| Cornell Notes                  | 6         | 14.29| 4    |
| Learning Portfolio             | 4         | 9.52 | 5    |
| Wrapper                        | 3         | 7.14 | 6    |
| Session Reflection Log         | 0         | 0    | 7    |
| **Totality**                   | **42**    | **100**|      |

Many students believe that science and chemistry in particular are essential for the societal advancement. However, as tackled earlier, students perceive science as a difficult subject removed from reality, and less fun. These reasons promoted researches like the current undertaking to peruse into the students personal point of view on the instructional provisions in science classrooms. What activities, materials, and instructional set-up may be given to augment students’ positive outlook regarding science? On table 19 it can be gleaned that discussion/feedback and learning community and goal-setting are the top meta-activities that students felt strongly about that help them “feel” like a scientist. There are two major things that have to be addressed here. First, what do we mean by “feel like a scientist” or have the students felt like one? Second, what are the common things about these three activities that when used as an instructional strategy, students had that “sense” of being a scientist. To answer these queries, students’ exit interviews provide a glimpse of the subjects’ thoughts on the matter. The table that follows shows a summary of the students responses when they were asked “about feeling” like a scientist. For students who responded negatively, believed that laboratory takes at the centerpiece of chemistry instruction. They contend that actual manipulations of chemicals and apparatuses would lend those experiences akin to scientific endeavors. In contrast, there were students who upon recognition at the outset that chemistry 1 course is only lecture made use of instructional provisions like, reflection, summarizing, inferring, and even simple and mental manipulations like naming, formula writing, predicting patterns in...
periodic table, and quantum number computations which has an effect as what “laboratory” can do. Therefore, feedback-discussion, learning community, and goal-settings are perfect avenues for students to explore these activities that provided the necessary engagements usually afforded by laboratory activities. This finding confirms earlier works that metacognition plays a key role in teaching in the theoretical framework of Teaching Science as Inquiry (Seraphin, Philippoff, Kaupp, & Vallin, 2012). This does not mean however that these activities may substitute the laboratory. While metacognition compliments with inquiry and other methods of teaching science, through regulation of their own learning and consequently do appropriate adjustments, students may still feel deprived of authentic science experiences deemed to promote positive attitude toward science among students.

Conclusion

In the light of the findings and the foregoing interpretation made, it was concluded that metacognitive activities integrated in the different learning episodes of Chemistry instruction rendered positive effects to the subjects’ cognition, and affect to some extent. Specifically, the intervention scheme drew improvements in the subjects’ chemistry performance and motivation.

Recommendations

With the validation of the points raised in this study and upon presentation of its output, the following recommendations are made:

1. Since in the present study, the subjects were exposed only to three-month intervention, a prolonged exposure to metacognitive environment is worth exploring. Further, ample time may be allocated for students to interact in groups. This could be done with some tasks at hand which will serve as a fulcrum so that discussion will not veer from the learning intent.

2. Topics which are abstract in nature may be taught using some activities that will relate to the tangible and macroscopic world. Analogy and activities with chips, and manipulative devices may be used. Further, Hands-on activities that provide rich opportunity for students to have a glimpse of the world of scientists are suggested to be in place.

3. Science courses such as chemistry are suggested to be taught with laboratory following the teaching science inquiry philosophy.

4. Since goals whether long term just like finishing the degree or short-term like passing a term or the course has an impact on how students will likely perform in the class, course and class advisers are encouraged to let their students write their goal statements. Hence; schools may develop advisory system or career-guidance program whether in the institution or college levels.

5. Schools could provide ample and varied opportunities for students to succeed and move up in the academic rung. Schools can design online or semi-online platform to cater to working students, second course runners, and working professionals whose circumstance could hamper in their maximum compliance and access to classroom activities.

6. For the curriculum framers, courses such as Environmental Science, Science Technology and Society may be offered in lieu of lecture classes on Chemistry or Physics in the curriculum of non-science majors so that relevance to students’ personal lives and career may be achieved.

References:

1. Elliott, S., Kratochwill, T., Littlefield, J., & Travers, J. (1996). Educational Psychology: effective teaching, effective learning. Times Mirror Higher Education Group.
2. Fogarty, R. (1994). The Mindful School: How To Teach for Metacognitive Reflection. IRI/Skylight Publishing, Inc., 200 East Wood Street, Suite 274, Palatine, IL 60067.
3. Padolina, M. C., & Magno, M. (2003). Chemical education in the Philippines. Quezon City: UP Open University and UP ISMED.
4. Papaleontiou-Louca, E. (2008). Metacognition and theory of mind.
5. Lucas, M. R. D., & Corpuz, B. B. (2007). Facilitating learning: A metacognitive process. M. Mla. Lorimar Publishing.
6. Olson, M. H., & Hergenhahn, B. R. (2012). Introduction to theories of learning. 9th Ed. Singapore: Prentice Hall.
7. Schunk, D. (2004). Learning theories: An educational perspective. New Jersey: Pearson Prentice Hall.
8. Ali, T. (2012). A case study of the common difficulties experienced by high school students in chemistry classroom in Gilgit-Baltistan (Pakistan). SAGE Open, 2158244012447299.
9. Anderson, K. J. B., Courter, S. S., McGlamery, T., Nathans-Kelly, T. M., & Nicometo, C. G. (2010). Understanding engineering work and identity: a cross-case analysis of engineers within six firms. *Engineering Studies*, 2(3), 153-174.

10. Bailey, P. D., & Garratt, J. (2002). Chemical education: theory and practice. *University Chemistry Education*, 6(2), 39-57.

11. Breuer, S. (2002). Does chemistry have a future. *University Chemistry Education*, 6(1), 13-16.

12. Broman, K., Ekborg, M., & Johneuls, D. (2011). Chemistry in crisis? Perspectives on teaching and learning chemistry in Swedish upper secondary schools. *Nordic Studies in Science Education*, 7(1), 43-53.

13. Butler, M. B. (2009). *Motivating Young Students to be Successful in Science: Keeping It Real, Relevant and Rigorous*. National geographic, July.

14. Cardellini, L. (2012). Chemistry: why the subject is difficult?. *Educacion quimica*, 23(1), 305-310.

15. Chalmers, C. (2009). *Group metacognition during mathematical problem solving*. Cooper, M. M., & Sandi-Urena, S. (2009). Design and Validation of an Instrument To Assess Metacognitive Skillfulness in Chemistry Problem Solving. *Journal of chemical education*, 86(2), 240-245.

17. Cornford, I. R. (2002). Learning-to-learn strategies as a basis for effective lifelong learning. *International Journal of Lifelong Education*, 21(4), 357-368.

18. De Jong, O. (2000). Crossing the borders: Chemical education research and teaching practice. *University Chemistry*, 4(1).

19. Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2007). Nonscience majors learning science: A theoretical model of motivation. *Journal of Research in Science Teaching*, 44(8), 1088-1107.

20. Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching*, 46(2), 127-146.

21. Glynn, S., & Koballa, T. (2006). *Motivation to learn college science*. In Joel J. Mintzes and William H. Leonard (Eds.) *Handbook fo College Science Teaching* (pp. 25-32). Arlington, VA: National Science Teachers Association Press.

22. Holbrook, J. (2005). Making chemistry teaching relevant. *Chemical Education International*, 6(1), 1-12.

23. Johnstone, A. H. (2000). Chemical education research: where from here. *University Chemistry*. 24. Johnstone, A. H. (1997). And some fell on good ground. *University Chemistry Education*, 1(1), 8-13.

25. Lin, X. (2001). Designing metacognitive activities. *Educational Technology Research and Development*, 49(2), 23-40.

26. Lin, X., Schwartz, D. L., & Hatano, G. (2005). Toward teachers' adaptive metacognition. *Educational psychologist*, 40(4), 245-255.

27. Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision(SAI II). *Journal of Research in Science Teaching*, 34(4), 327-336.

28. Nbibia, J. B., & Viko, B. (2010). Effect of instruction in metacognitive self-assessment strategy on chemistry students’ self-efficacy and achievement. *Academia Arena*, 2(1), 1-10.

29. Peklaj, C. (2001). Metacognitive, affective-motivational processes in self-regulated learning and students achievement in native language. *jezik*, 200, 3550.

30. Price, W. S., & Hill, J. O. (2004). Raising the status of chemistry education. *University Chemistry Education*.

31. Pulmones, R. (2007). Learning chemistry in a metacognitive environment. *The Asia-Pacific Education Researcher*, 16(2), 165-183.

32. Rickey, D., & Stacy, A. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education*, 77, no. 7. 915-920.

33. Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational psychology review*, 7(4), 351-371.

34. Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish science education*, 4(2), 2.

35. TANNER, K. D. (2012). Promoting student metacognition. *CBE-Life Sciences Education*, 11(2), 113-120.

36. Chalmers, C., & Nason, R. A. (2003). *Developing Primary Students’ Group Metacognitive Processes in a Computer Supported Collaborative Learning Environment*. A paper presented at the Joint AARE/NZARE Conference, Auckland.

37. Cornford, I. R. (2005). Cognitive and metacognitive strategies as a basis for effective lifelong learning: How far have we progressed. *University of Technology, Sydney*.

38. Curaraton, E.P. (2009). *Self-learning Experience Approach in the performance of science students*. Unpublished Master’s Thesis, Cebu Normal University.

39. Dawson, T. L. (2008). Metacognition and learning in adulthood. *Prepared in response to tasking from ODNI/CHCO/IC Leadership Development Office, Developmental Testing Service, LLC.*
Impact Factor:

| Journal | Impact Factor |
|---------|---------------|
| ISRA (India) | 4.971 |
| ISI (Dubai, UAE) | 0.829 |
| GIF (Australia) | 0.564 |
| JIF | 1.500 |
| SIS (USA) | 0.912 |
| PHHH (Russia) | 0.126 |
| ESJI (KZ) | 8.997 |
| SJIF (Morocco) | 5.667 |
| IBI (India) | 4.260 |
| ICV (Poland) | 6.630 |
| PIF (India) | 1.940 |
| OAJI (USA) | 0.350 |

40. Liu, R., Qiao, X., & Liu, Y. (2006). A paradigm shift of learner-centered teaching style: Reality or illusion. *Arizona Working papers in SLAT, 13*, 77-91.

41. Lovett, M. C. (2008). Teaching metacognition. *Unpublished paper presented at the Educause*.

42. Perez, L. (2016). Peer-assisted learning strategies in teaching trigonometry. *Unpublished Master’s Thesis, Cebu Normal University*.

43. Su, G.T. (n.d.). Effects of starter-based experiment approach in physics: performance and values development. *Unpublished Master’s Thesis, Cebu Normal University*.

44. Cooper, S. (2016). *John Flavell Metacognition Theory*.

45. (n.d.). Retrieved April 12, 2016 from [http://www.lifecircles-inc.com/Learningtheories/constructivism/flavell.html](http://www.lifecircles-inc.com/Learningtheories/constructivism/flavell.html)

46. Cooper, S. (2016). *Metacognitive Development in Professional Educators*.

47. (n.d.). Retrieved April 11, 2016 from [http://www.lifecircles-inc.com/Metacognition.html](http://www.lifecircles-inc.com/Metacognition.html)

48. Jordan, J. (2011). *Teacher Practices and High School Chemistry Students’ Metacognitive Skillfulness*.

49. (n.d.). Retrieved May 15, 2016 from [http://tigerprints.clemson.edu/all_dissertations/688/](http://tigerprints.clemson.edu/all_dissertations/688/)

50. Livingston, J. (1997). *Metacognition: Teaching students to think about their thinking*. Retrieved April 11, 2016 from [https://www.csun.edu/~vceed002/ref/reasoning/metacognition/index.html](https://www.csun.edu/~vceed002/ref/reasoning/metacognition/index.html)

51. McLeod, S. (2014). *Lv Vygotsky: Social learning theory*.

52. (n.d.). Retrieved April 11, 2016 from [http://www.simplypsychology.org/vygotsky.html](http://www.simplypsychology.org/vygotsky.html)
AN ANALYSIS OF BRINES FOR CHROMIUM CONTENT BY SPECTROPHOTOMETRIC METHOD USING CO-PRECIPITATION CONCENTRATION

**Abstract:** Coprecipitation of chromium on magnesium hydroxide was studied. Coprecipitation mechanism was proposed. The use of high-frequency ultrasound (US) and simultaneous action of ultrahigh-frequency and low-frequency US for intensification of chromium coprecipitation was investigated. It has been found that dispersing and mixing effects are the determining factors of the US action on co-precipitation concentration. The method of spectrophotometric determination of chromium in brines was developed. The content of chromium in the natural brines of Ukraine was determined. It was shown that the use of double-frequent US allows us to increase the degree of chromium determination from 92-93% up to 96-98% and also to improve metrological characteristics.

**Key words:** Chromium, brines, ultrasound, coprecipitation, spectrophotometry, metrologic characteristics.

**Language:** English

**Citation:** Yurchenko, O. I., Chernozhuk, T. V., Baklanov, A. N., & Kravchenko, O. A. (2021). An analysis of brines for chromium content by spectrophotometric method using co-precipitation concentration. *ISIJ Theoretical & Applied Science*, 03 (95), 23-29. 
**Soi:** http://s-o-i.org/1.1/TAS-03-95-2  **Doi:** https://dx.doi.org/10.15863/TAS

**Scopus ASCC:** 1600.

**Introduction**
Chromium is toxic trace elements having cancerogenic effects. Its content is regulated in drinking water and food products [1,p.24; 2,p.662; 3,p.124], the maximum possible content of chromium is 0.1-0.5 mg/dm³. Brines are a raw material for production of various types of kitchen salt [4,p.158;5,p.576;6,p.763;7,p.45]. The content of...
The purpose of this work is to develop an environmentally safe methodology for spectrophotometric determination of chromium in brines using coprecipitation concentration with improved metrological characteristics.

Experimental

We used spectrophotometer SF-46, electronic scales OHAUS PA 64 (65/0.0001 g), ultrasound disperser UZDN, centrifuge T23, measuring laboratory flasks, according to DSTU 1770-74, electron ionomer Rn-673, bidistilled water.

To prepare standard chromium solutions, standard samples of composition of MSO solutions with a chromium concentration of 1 mg/l were used. Sodium chloride, phr., was further purified by recrystallization. HCl, phr., was further purified by isopiotic distillation.

A sample of kitchen salt with mass of 2.00 g is dissolved in 10 cm³ of bidistilled water, added with 0.05 cm³ of hydrochloric acid (1:1) and 10 cm³ of mixture of acetylacetone and chloroform (1:1), the mixture was shaken for 1 min, organic phase was separated. The water was transferred to a tube, pH was raised up to 6 with ammonia, and 10 cm³ of acetylacetone was added. The tube was placed in a magnetostrictive radiator and affected by a 44 kHz US system with an intensity of 2 W/cm² for 20 seconds. Then 0.5 cm³ of hydrochloric acid, 10 cm³ of acetylacetone were added to the tube and shaken for 1 minute. Chromium (III) detection limit - 0.01 mg/kg. For analysis, 10 g of brine with a sodium chloride content of not more than 200 g/cm³ was taken and brine was diluted with bidistilled water. 2 g of kitchen salt was dissolved in 10 cm³ of bidistilled water, 0.5 cm³ of hydrogen peroxide, was treated by ultrasound with frequency of 44 kHz, intensity of 2.0 W/cm² for 1 min. Then content of total chromium was determine.

Results and discussions

Figure 1 shows the dependence of the degree of destruction of organic compounds in the natural brines of the Geroyskoye source on the frequency of the US at the maximal possible intensity for modern piezoceramic emitters - 12 W/cm². From the experimental data, presented in Figure 1, it can be seen that with an increase in the frequency of US, the degree of chromium destruction decreases significantly. The decrease in the degree of ROP destruction is obviously explained by the fact that with an increase in the frequency of the US, an increase in the intensity of the US is also necessary to raise to the corresponding level of cavitation activity. It should also be noted that for solutions of kitchen salt and sea water, the similar dependencies of ROP destruction degree on the frequency of MW were obtained.

However, as the content of organic substances (humic and fulvic acids) in brine samples and sea water decreased, the dependence on frequency is less important; that can be explained by the fact that with a lower content of organic substances, a lower level of cavitation activity is needed for their destruction, which depends on the frequency of the US.

Figure 2 shows the dependence of degree of destruction of organic chromium compounds in brines on the intensity of US at its frequency of 400 kHz and the action time of 2 minutes. As follows from Figure 2, with the increase in US intensity, the degree of destruction of organic chromium compounds increases.

The effect of the time of US action on the degree of RUR destruction at different US frequencies was also investigated, while the intensity of the US was maximal possible - 12 W/cm². As follows from the results of the experiments given in Fig. 2, in order to achieve the ROP destruction rate 90%, the time of US action should be the longer the higher US frequency, since with an increase in the US frequency, it is necessary to raise the corresponding level of cavitation activity and increase the US intensity, which is limited by the mechanical strength of the piezoelectric power of US intensity not more than 12 W/cm². From the results of experiments, it also follows that it is possible to use ROP for destruction in brines of US action with frequency up to 200, 250 and 600 kHz, respectively, when the ROP destruction time increases up to 10 min [11, p.34].

However, with an increase of time of action of the US, the metrological characteristics of the Chromium determination results deteriorated in all samples. Moreover, with an increase in the frequency of US, for the destruction of organic compounds, a large intensity or duration of the US action was required. In the analyzed samples, characterized by a large content of organic substances, with an increase in the frequency of US, a significant deterioration in the metrological characteristics of the obtained results was observed. Therefore, the satisfactory metrological...
characteristics of the Chromium determination results in salt brines and solutions of kitchen salt were obtained with use of US with a frequency of up to 100 kHz. At the same time, compared with use of previously studied low-frequency range of US, the results of analysis, obtained using medium-frequency UZ had better reproducibility. It may be explained by higher level of stability of piezoelectric emitters.

Thus, for the destruction of organic substances in brains, US can be used in the frequency range from 18 to 100 kHz, and in sea water - from 18 to 200 kHz; the results can be obtained in the frequency range of 80-100 kHz, respectively.

The two types of bubbles are formed in the cavitation field: large deformed bubbles (VDB), which cause physicochemical effects: surface cleaning, mass exchange, erosion and small spherical bubbles (GSB), during the splitting of which sound chemical reactions and sonoluminescence occur. When using the combined action of high (1 MHz) and low frequencies (18-47 kHz), the total mass of the GSB prevails over the total mass of the airborne bombs. In this regard, the use of compatible high and low frequency SLM for the destruction of organic compounds in salt solutions and brines has been studied. In this case, laboratory equipment was used, the same as in the study of the combined action of high and low frequencies in sonoluminescent spectroscopy.

The change in frequency of the low-frequency US from 18 up to 47 kHz by the value of the degree of ROP destruction in the brines was not affected, a comparison of the obtained results using high-frequency US with a frequency of 1 or 2 MHz show us that the best results were obtained in the first case (Table 2).

The optimal intensity of the high-frequency US and the low-frequency US depends on their relation, the type of the analyzed product and frequency of high-frequency US (Table 1). In this case, the optimal intensity is an intensity that ensured the achievement of the maximum possible degree of destruction of organic compounds. It should be noted that the optimum intensity when using only one low-frequency US that is significantly higher and ranged from 7.0 to 10 W/cm² [13,p.67; 14,p.77; 15,p.17].

The action time of the two frequency US should be not less than 0.5 minutes for sea and river water, and not less than 1.0 minutes for brines of Ukrainian sources, and for brines of Lake Jaksa-Archeologist (Kazakhstan) - 2 minutes, since the last source is characterized by abnormally high content of organic substances (Table 3). It should also be noted that even with a 3 times increase in time of US action, the degree of destruction of organic compounds does not changes. The order of switching on low and high frequency US did not affects the results.

The proposed method provides the obtained results of analysis with better metrological characteristics than standard method, based on destruction of organic compounds in salt solutions and brines. An improvement of metrological characteristics is explained by the higher stability of ultrasonic emitters at low US intensities.

The most expressive method is the method based on the use of low-frequency US (10 W/cm²) and the method based on the use of low-frequency US with hydrogen peroxide addition, but the last method is hindered by the need to introduce additional reagents. The maximal possible degree of ROP destruction is provided by the method, based on the use of medium frequency UZ (80-100 kHz) and the method based on the use of simultaneous action of high and low frequency US. The first method does not require complex design and provides results with better metrological characteristics, and the second is more expressive.

**Conclusions**

1. Coprecipitation of chromium on magnesium hydroxide was studied. It has been shown that at optimal conditions degree of coprecipitation does not exceed 93%, respectively. To increase degree of coprecipitation, it is recommended to use US action.

2. We studied the use of US in determining chromium in brines: how to transfer chromium compounds to the forms undergoing, coprecipitation, as well as how to intensify concentration by coprecipitation on magnesium hydroxide.

3. A project of an express method for determining chromium in brines has been developed, including ROP destruction, coprecipitation of chromium on magnesium hydroxide with US process intensification. In the resulting chromium concentrate, the SF was determined by the diffenylcarbazide method at 535 nm. Lower limit of chromium detection in brines id 0.001 mg/kg, relative standard deviation of analysis results does not exceed 0.08.

**Impact Factor:**

| Journal       | Impact Factor |
|---------------|---------------|
| ISRA (India)  | 4.971         |
| ISI (Dubai, UAE) | 1.582         |
| GIF (Australia) | 0.564         |
| JIF           | 1.500         |
| SIS (USA)     | 0.912         |
| PIIH (Russia) | 0.126         |
| ESJI (KZ)     | 9.035         |
| IBI (India)   | 4.260         |
| SJIF (Morocco) | 7.184         |
| OAJI (USA)    | 0.350         |

Philadelphia, USA

25
Impact Factor:

| Journal   | Impact Factor |
|-----------|---------------|
| ISRA (India) | 4.971         |
| ISI (Dubai, UAE) | 0.829       |
| GIF (Australia)    | 0.564         |
| JIF               | 1.500         |
| SIS (USA)         | 0.912         |
| ESJI (KZ)         | 8.997         |
| SJIF (Morocco)    | 5.667         |
| РИНЦ (Russia)     | 0.126         |
| IBI (India)       | 4.260         |
| ICV (Poland)      | 6.630         |
| PIF (India)       | 1.940         |
| OAJI (USA)        | 0.350         |

Fig.1 Ultrasound frequency dependence on the degree of destruction of organic compounds in the natural brines

Fig.2 Ultrasound intensity dependence on the degree of destruction of organic compounds in the natural brines
Table 1. Ultrasound frequency influence on the degree of destruction of Chromine ROP

| Sample                                      | The degree of destruction of organic compounds % |
|---------------------------------------------|--------------------------------------------------|
|                                             | 1 Mhz                                            |
|                                             | 2 Mhz                                            |
| Brine from Sloviansk factory                | 99                                               |
|                                              | 98                                               |
| Brine from Bascunchak lake, Russia          | 99                                               |
|                                              | 96                                               |
| Brine from Barsa-Kelmez lake, Kazakhstan    | 99                                               |
|                                              | 96                                               |
| Brine from Henichesk factory                | 97                                               |
|                                              | 97                                               |
| Sea water, Yalta village                    | 99                                               |
|                                              | 97                                               |
| River water, Bahmut river                   | 99                                               |
|                                              | 96                                               |

Table 2. Ultrasound intensity influence on the degree of destruction of organic compounds in the natural brines

| US intensity, W/sm² | degree of destruction of organic compounds % at US intensity, W/sm² |
|---------------------|---------------------------------------------------------------------|
|                     | 1   | 2   | 3   | 4   | 5   | 6   |
| Brine from Heroiske factory |     |     |     |     |     |     |
| 1                   | 45  | 61  | 74  | 86  | 90  | 96  |
| 2                   | 93  | 98  | 97  | 99  | 98  | 99  |
| 3                   | 93  | 96  | 98  | 99  | 99  | 99  |
| 4                   | 943 | 97  | 98  | 99  | 99  | 99  |
| Brine from Sloviansk factory |     |     |     |     |     |     |
| 1                   | 66  | 67  | 72  | 83  | 87  | 92  |
| 2                   | 97  | 98  | 98  | 99  | 98  | 99  |
| 3                   | 98  | 99  | 98  | 99  | 99  | 99  |
| 4                   | 98  | 98  | 98  | 99  | 99  | 99  |
| Brine from Barsa-Kelmez lake, Kazakhstan |     |     |     |     |     |     |
| 1                   | 47  | 57  | 65  | 743 | 75  | 80  |
| 2                   | 90  | 93  | 98  | 98  | 98  | 99  |
| 3                   | 93  | 96  | 98  | 99  | 99  | 99  |
| 4                   | 96  | 976 | 98  | 99  | 99  | 99  |
**Table 3. Ultrasound time influence on the degree of destruction of ROP**

| Sample                                           | US time, min. | The degree of destruction of ROP, % |
|--------------------------------------------------|---------------|-------------------------------------|
| Brine from Sloviansk factory                     | 0.5           | 94                                  |
|                                                  | 1.0           | 98                                  |
|                                                  | 2.0           | 99                                  |
|                                                  | 3.0           | 99                                  |
|                                                  | 4.0           | 99                                  |
| Brine from Barsa-Kelmez lake, Kazakhstan         | 0.5           | 83                                  |
|                                                  | 1.0           | 87                                  |
|                                                  | 2.0           | 98                                  |
|                                                  | 3.0           | 98                                  |
|                                                  | 4.0           | 99                                  |

**Table 4. The results of chromine determination (n=5; p=0.95)**

| Sample                                           | Found out, mg/kg |
|--------------------------------------------------|------------------|
| Brine from Sloviansk factory                     | 0.033/0.092      |
| Brine from Barsa-Kelmez lake, Kazakhstan         | 0.543/0.092      |

**Table 5. Comparative characteristic of destruction methods of ROP in brines (n=5; p=0.95)**

| Factor                                           | Factors value   |
|--------------------------------------------------|------------------|
| Destruction of ROP by the standard method–US of 22 kHz frequency |
| Optimal US intensity                             | 10 W/sm²         |
| Time of the process                              | 0.3–0.5 min.     |
| Standard deviation                               | 0.070–0.087      |
| Destruction of ROP by the method–with 100 kHz US frequency |
| Optimal US intensity                             | 12 W/sm²         |
| Time of the process                              | 2–4 min.         |
| Standard deviation                               | 0.062–0.071      |
Impact Factor:

| Journal       | Impact Factor |
|---------------|---------------|
| ISRA (India)  | 4.971         |
| ISI (Dubai, UAE) | 0.829      |
| GIF (Australia) | 0.564       |
| JIF           | 1.500         |
| SIS (USA)     | 0.912         |
| РИНЦ (Russia) | 0.126         |
| ЕSJI (KZ)     | 8.997         |
| ICV (Poland)  | 6.630         |
| PIF (India)   | 1.940         |
| IBI (India)   | 4.260         |
| SJIF (Morocco)| 5.667         |
| OAJI (USA)    | 0.350         |

References:

1. Lurie, Yu.Yu. (1984). *Analiticheskaya himiya stochnyh vod*. (p.448). Moscow: “Chemistry”.
2. Sato, A. (2019). * Bunseki kagaky*. V.24,(10), pp.663-667.
3. Sato, A. (2020). * Bunseki kagaky*. V.34,(10), pp.123-127.
4. Yurchenko, O.I. (2019). *Theoretical & Applied Science*. V. 33, pp.158-163.
5. Baklanov, A.N. (2007). *Anal. Chem.*, V.62, pp.575-582.
6. Chmilenko, F.A. (1993). *Ukrainian chemical journal*. V.59, pp.762-766.
7. Kuzmin, N.M. (1996). *Anal. Chem.*, V.1, pp.44-48.
8. Volkova, N.N. (1987). *Anal. Chem.*, V.42, pp.246-251.
9. Chmilenko, F.A. (1991). *Ukrainian chemical journal*. V.57, pp.37-39.
10. Avruhina, A.K. (1979). *Analytycheskaya himiya choma*. (p.222). Moscow: “Chemistry”.
11. Margulis, M.A. (1986). *Zvukohimicheskiye reakcii*. (p.228). Moscow: “Chemistry”.
12. Reznikov, A.A. (1970). *Metody analiza prirodnyh vod*. (p.480). Moscow: “Nauka”.
13. Furman, A.A. (2020). *Neorganicheskie chloridy*. (p.410). Moscow: “Chemistry”.
14. Furman, A.A. (2020). *Povarennya sol*. (p.287). Moscow: “Chemistry”.
15. Petrov, O.V. (2020). *Metody analiza rassolov*. (p.176). Moscow: “Chemistry”.
DEVELOPMENT OF THE FOUNDATIONS OF INTEGRATED METHODS OF TEACHING THEORETICAL KNOWLEDGE IN THE DISTANCE EDUCATION SYSTEM USING INFORMATION TECHNOLOGY

Abstract: This article highlights the issues of studying and mastering the complex theoretical foundations of special subjects for students and undergraduates of higher educational institutions. At the same time, a wide application of the information technology system is proposed and a scheme for studying and mastering the theoretical foundations of special subjects in distance learning has been developed.

Key words: Master, student, integral methods, deterministic, stochastic communication, road transport, reliability theory, distance learning, information technology.

Language: English

Citation: Karimkhodjaev, N., Turakhujayeva, N. N., & Mirzakarimov, R. H. (2021). Development of the foundations of integrated methods of teaching theoretical knowledge in the distance education system using information technology. ISJ Theoretical & Applied Science, 03 (95), 30-35.

Soi: http://s-o-i.org/1.1/TAS-03-95-3 Doi: https://dx.doi.org/10.15863/TAS

Scopus ASCC: 3304.

Introduction

It is known that obtaining knowledge with theoretical features has certain difficulties and requires serious work from the student. Since theoretical knowledge is outside our field of vision, we have very little chance of mastering it by sight. Such knowledge is mainly acquired through independent and mental thinking. Consequently, such knowledge depends on the student's ability to think, visualize material using spatial thinking, have sufficient knowledge of related disciplines and other similar characteristics of perception. The higher a student's thinking ability, the higher his or her chances of learning. But in general, with the exception of most students, they acquire analytical knowledge with a number of difficulties. To facilitate the development of complex theoretical knowledge by students and masters in the educational process of universities, along with traditional methods of teaching academic disciplines, new information technologies are
increasingly used, which contributes to a change in the very method of presenting material. The use of computer technologies (CT) in the learning process increases the quality of assimilation and educational information, makes the process of their learning more effective and productive, provides an increase in motivation to gain knowledge of a theoretical and practical nature [1,2].

The practice of using computers initiates the emergence of a new generation of CT, which, in turn, makes it possible to improve the quality of education, create new means of educational influence, effectively interact with computers, and develop the information competence of teachers and students. The introduction of CT in education can be seen as the beginning of a revolutionary transformation of traditional teaching methods and technologies and the entire education sector. Communication technologies play an important role at this stage: telephone means of communication, television, which are mainly used in managing the learning process in distance learning systems.

An example of the successful implementation of CT in modern educational institutions is the introduction of the Internet into universities with its practically unlimited possibilities for collecting and storing information, transmitting it to each user [4].

Orientation to innovative technologies in the field of education, modern material and technical base, highly professional teaching staff - everything in a large educational, scientific and innovative complex of the country is aimed at producing competent specialists who are well-trained to create high-quality products, thinking progressively and creatively solving the assigned tasks ... The main educational value of information technology is that it allows you to create a brighter interactive learning environment with unlimited opportunities available to both teachers and students. The advantages of information computer technologies in comparison with traditional ones are manifold. In addition to the possibility of a more illustrative, visual presentation of the material, effective verification of knowledge and everything else, they include the variety of organizational forms in the work of students, methodological techniques in the work of a teacher. In contrast to conventional technical teaching aids, information technology allows not only to saturate the student with a large amount of knowledge, but also to develop intellectual, creative abilities, their ability to independently acquire new knowledge, to work with various sources of knowledge [2].

II. METHOD OF EXPERIMENT

At the same time, the basic information about theoretical knowledge to students is first of all provided by the teacher during the lecture, and then this knowledge is supplemented with the help of practical exercises. However, even the knowledge gained in these classes is still insufficient. In order to fully master the theoretical knowledge in the chosen subject, the student must be able to work independently, develop practical skills based on the knowledge gained, have excellent knowledge of the use of CT in the educational process, and also be able to express their personal opinions and suggestions. One of the most important conditions for meeting these requirements is the student's interest in the subject being studied. To implement these requirements, students are offered the following integrated schematic methods that facilitate the acquisition of theoretical knowledge and help applicants acquire knowledge in developing memorization skills and applying them in practice for a long time.

For example, the following theoretical material is given: “Foundations of the theory of reliability of road transport. Failure is a random event, a study of its current distribution laws. "The solution of these problems is based on the knowledge of probability theory, statistical mathematics, physics, road transport and its technical operation, as well as other similar disciplines and has a high complexity. Therefore, it is desirable that the first information about the theory of reliability is explained by the teacher during lectures in connection with the provisions of applied, statistical mathematics and information technology systems.

In modern conditions, the importance of applied mathematics is invaluable, with the help of which it is possible to predict random events in various areas of technical and economic sectors and find the optimal ones, i.e. the most profitable technical and economic solutions based on an information technology system without high costs. If we consider each case as an event, its occurrence depends on several arguments and forms a mathematical relationship between the event and the arguments, and this relationship is divided into two types [3]:

- deterministic communication;
- stochastic connection.

Deterministic relationships are based on known patterns, and such related events occur on the basis of these patterns. In a deterministic relationship, the value of each argument corresponds to one function value. An example of a deterministic relationship is a freely falling object. In this case, each value of the path traversed by the object corresponds to a certain value of time. The path traversed by a freely falling body is determined by this well-known equation.

\[ S = \frac{gt^2}{2} \]

Stochastic relationship is a relationship in which each value of the argument has a different value of the distribution density of functions. Stochastic relationships are presented using mathematical models, and in many cases, rough conclusions are drawn about the relationships considered using these models. Mathematical models are used in various
fields and sectors of the economy. For example, in engineering, biology, chemistry, medicine, economics and so on. Mathematical models allow expressing the essence of the process under consideration using a mathematical model and choosing optimal solutions for it. In order to objectively (clearly) express the patterns of the processes under consideration, mathematical models must take into account all internal and external factors influencing this process. To achieve this state, it is necessary to plan an experiment on the process, conduct it, statistically process and analyze the results using computer technology.

All aspects of human activity can be expressed using mathematical models, and all internal and external factors affecting each process under consideration are random. And the influence of these random factors on the process is of a guided nature.

For example, the efficient operation of a service station (STO) is inextricably linked with the accidental entry of cars into the station, their presence at it, as well as the random time spent on maintenance (MOT) and car repairs. It also depends on the random arrival time of the customer at the dealership and the random customer service time. In such conditions, that is, under the influence of several random factors per process, it will be necessary to find optimal solutions for a number of indicators, such as equipment, number of workers, working capacity, quality of repair, and so on.

Thus, the relationship between all the processes under consideration and the factors that randomly affect them, and the identification of the mathematical expression of these laws, the search for optimal (most convenient) solutions and the correct organization of the experiment can be carried out only with the help of probability theory, statistical mathematics and information technology.

The mathematical theory of reliability is important in solving all problems of vehicle maintenance and repair. In particular, the issues of improving the quality of products manufactured in the automotive industry are absolutely impossible without the theory of reliability. Because the main components of reliability indicators are:

- reliability;
- durability;
- maintainability;
- preservation.

The numerical values of such classifications are determined based on the theory of reliability. This theory serves to study the regularities of the causes of defects in products, to determine the wear time of the product and to develop measures to improve its reliability. Any product manufactured in mechanical engineering must have high performance based on experimental tests. The results of such an experiment are statistically analyzed and the following random phenomena are studied:

- random phenomena;
- random variables;
- random processes.

Random processes are such a connection that it either happens or does not happen. For example, the transmission of a car may or may not work for 400-500 hours of operation. This means that transmission failure at regular intervals is a random event. The probability of propagation of random events is expressed by \( R(L) \), and the density - \( R(L) \). The probability of an event occurring is determined prior to experimental testing and, under normal conditions, is expressed as follows:

\[
P(L) = \frac{m(L)}{n}
\]

where:
- \( m(L) \) – the number of favorable conditions for the event;
- \( n \) – is the total number of possibilities.

The distribution density of random events is determined from the results of experimental tests, i.e.:

\[
R(L) = \frac{m \ast (L)}{N}
\]

where:
- \( m \ast (L) \) – the number of occurrences of a random event;
- \( N \) is the total number of experiments performed.

Random values are numerical values that can be the result of an experiment and have any previously unknown values. For example, the distance traveled by a car's braking system to failure is a random variable. The laws of analytical distribution of random variables are usually written in the following form:

\[
Y = f(x)
\]

where:
- \( x \) – value of a random variable (argument);
- \( Y \) – distribution density (function).

A random process is defined as a function that, as a result of experiments, takes on a random form that was not previously known. Acceptance of a random function of a specific random form is also its implementation.

For example, abrasion of cylinder liners, piston rings, liners and bearings of an automobile engine. There are the following main types of wear of engine parts: abrasion and scuffing of rubbing surfaces, which can be mechanical, corrosive and abrasive. The nature, reasons for the appearance, quantitative assessment and determination of patterns that describe the essence of the flow of such types of wear are also revealed by probabilistic methods of the theory of probability and mathematical statistics [five]. Under normal operating conditions, it is the abrasion of the parts that determines the life of the engine.

As mentioned above, random variables are represented by the laws of probability and correspond to the physical nature of the considered random events. Probability laws can be one-dimensional or multi-dimensional.
Impact Factor:

| Journal     | Impact Factor |
|-------------|---------------|
| ISRA (India)| 4.971         |
| ISI (Dubai, UAE) | 0.829   |
| GIF (Australia)  | 0.564   |
| JIF          | 1.500         |
| SIS (USA)    | 0.912         |
| ICV (Poland) | 6.630         |
| PIIH (Russia)| 0.126         |
| PIF (India)  | 1.940         |
| ESJI (KZ)    | 8.997         |
| IB (India)   | 4.260         |
| SJIF (Morocco)| 5.667   |
| OAJI (USA)   | 0.350         |

The numerical values of the reliability indicators in the operating conditions of the car and its components are determined using the laws of random events, which are based on:

The density of the function of the law of normal distribution is determined by the following expression:

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{\frac{-(x-\overline{x})^2}{2\sigma^2}} \]

- \( f(x) \) – distribution density of the law;
- \( x \) – is a random variable;
- \( \overline{x} \) – mean mathematical value of a random variable;
- \( \sigma \) – standard deviation \( \sigma = 2.72 \)

While the normal distribution law is a process of gradual wear of automobile parts, the mathematical model of the exponential distribution law represents the state of failure in the theory of reliability. Such pressure failures occur during overload and heat stress, for example, failure of engine parts at engine temperatures above 100 °C, lamp burning in case of overvoltage, etc.

The exponential distribution reflects the processes of replacing broken parts, lubricating, adjusting engine components and other similar maintenance operations for cars at service stations.

The laws of exponential distribution also play an important role in the theory of reliability and are used to determine the numerical values of vehicle reliability indicators.

The distribution density of the exponential distribution law is expressed by this formula:

\[ F(t) = e^{-\omega t} \]

Where:

- \( T \) – is a random variable, time or distance traveled by the vehicle (hour, day, month, year or m, km);
- \( \omega \) – parameter of the regularity or density of its distribution;
- \( e \) – random event per unit of time, failure / hour., refusal/km.

In addition to these laws, there are a number of laws in the field of car operation, including: Poisson distribution law, Weibul distribution law, gamma distribution law and others.

III. EXPERIMENTAL RESULTS

To master the above material, a master student or student must solve examples and problems in practical classes and work on himself independently. In addition, the student summarizes his opinions about the assimilated material of analysis and places them in the integrated circuit shown in the picture 1.

IV. CONCLUSIONS

1. When analyzing the coverage of the issues of studying and mastering the complex theoretical foundations of special subjects for students and undergraduates of higher educational institutions in distance learning, it was determined that the relationship between all the considered processes and factors that influence them randomly, and the identification of the mathematical expression of these laws, the search for optimal (the most convenient) solutions and the correct organization of the experiment can only be carried out with the help of probability theory, statistical mathematics and information technology.

2. An integrated circuit for the study of complex theoretical knowledge has been developed, in which a student or master's degree student summarizes and places his views on the material learned and analysis.
Impact Factor:

ISRA (India) = 4.971  SIS (USA) = 0.912  IJV (Poland) = 6.630
ISI (Dubai, UAE) = 0.829  PHH (Russia) = 0.126  PIF (India) = 1.940
GIF (Australia) = 0.564  ESJI (KZ) = 8.997  IBF (India) = 4.260
JIF = 1.500  SJIF (Morocco) = 5.667  OAJI (USA) = 0.350

Mathematical foundations of the theory of reliability

Random events, quantities and processes

Probability theory

Relationship between random events and arguments

Determinant

Stochastic

Link availability status

Events with specific laws

Previously unknown events

Various physical laws

Mathematical models

Representation of laws (model)

Normal, Exponential, Weibul, Poisson and others

Working areas

Some physical phenomena

The image of various vital and production functional phenomena, etc.

Personal opinion of the student, suggestions

Picture 1. Integrated circuit for studying complex theoretical knowledge
| Impact Factor: | ISRA (India) = 4.971 | SIS (USA) = 0.912 | ICV (Poland) = 6.630 |
|---------------|----------------------|-----------------|----------------------|
|               | ISI (Dubai, UAE) = 0.829 | PIIHII (Russia) = 0.126 | PIF (India) = 1.940 |
|               | GIF (Australia) = 0.564 | ESJI (KZ) = 8.997 | IBI (India) = 4.260 |
| JIF           | 1.500                | SJIF (Morocco) = 5.667 | OAJI (USA) = 0.350 |

References:

1. Griban, O.N. (2012). Komp’uternye tehnologii kak usloviy kachestvennoj professional’noj podgotovki studentov vuzov. Pedagogicheskoe obrazovanie v Rossii. Ekaterinburg. №2, pp. 113-116.

2. Demkin, V. P., & Mozhaeva, G. V. (2003). Organizatsiya uchebnogo processa na osnove tehnologij distancionnogo obuchenija. Tomsk.

3. Dillon, B., & Singh, U. (1984). Inzhenernye metody obespechenija nadjozhnosti dvigatelej. (p.318). Moscow: Mir.

4. (n.d.). Innovacionnye tehnologii v uchebnom processe. Materialy 50-j nauchnoj konferencii aspirantov, magistrantov i studentov (Minsk, 28 marta 2014 goda).

5. Karimhodzhaev, N., Almaataev, T.O., & Odilov, H.R. (2020). Osnovnye prichiny, vyzyvaushhie iznos detalej avtotransportnyh sredstv, jekspluatuirushhhsja v razluchenikh prirodno-klimatichestkih uslovijah. Universum: tehnicheskie nauki : elektron. nauchn. zhurn. № 5 (74). URL: Retrieved from https://7universum.com/ru/tech/archive/item/9435, pp.68-73.

6. Kacman, Jy.Ja. (2008). Statisticheskaja obrabotka jeksperimental’nyh dannyh. (p.37). Tomsk. Izd-vo TPH.

7. Kobzar’, A.I. (2006). Prikladnaja matematicheskaja statistika. (p.816). Moscow: FIZMATLIT.

8. Kolchin, A.I., & Demidov, V.P. (2008). Raschjot avtomobil’nyh i traktornyh dvigatelej. (p.496). Moscow: "Vysshaja shkola".

9. Kramarenko, G.V., Salimov, A.U., Karimhodzhaev, N., & Kaumov, K.K. (1992). Kachestvo topliva i nadezhnost’ aviotraktornyh dvigatelej. (p.126). Tashkent: Fan.

10. (1995). Nadjozhnost’ tehническиh sistem. Spravochnik. (p.672). Moscow: "Vysshaja shkola".

11. Baranov, Jy.P., et al. (1983). Pod red. Kramarenko G.V. Tehnicheskaja jekspluatacija avtomobilej. (p.488). Moscow: Transport.
MODELING OF THE COKING PROCESS

Abstract: The article is devoted to the modeling of coking as the most common conversion process of vacuum residue in oil refineries. The main parameters of the process and the impact of the products on the product and characteristics are taken into account. The main features of each process (chemistry, kinetics and thermal decomposition of asphalts) are summarized. Some dependencies published in the literature are evaluated and used to predict the yield and properties of coke products.

Key words: Coking process, kinetic parameters, oil, atmospheric residue, resin, asphaltene.

Language: English

Citation: Quliyeva, A. N., & Allahverdiyeva, G. (2021). Modeling of the coking process. ISJ Theoretical & Applied Science, 03 (95), 36-41. 

Method

Oil refineries with coking facilities are often referred to as continuous refineries. The advantage of coking is the inherent flexibility of the conversion process of various raw materials, which allows to solve the problem of reducing the demand for heavy oil by switching to the production of more expensive and lighter products.

One of the goals of the coking process may be the production of different types of coke. Coking can produce several types of coke, depending on the characteristics of the raw material, the design of the plant and the operating conditions [2]. Fuel coke, anode coke, needle coke.

By changing the operating parameters, it is possible to change the quality and productivity of coke products in accordance with the goals set by the refinery. The variable parameters in the coking plant are:

- Heat when leaving the furnace and at the entrance to the coking chambers. Heat is the main parameter that determines the coking conditions. Heat determines the quality of cokes;
- Pressure in the coking chamber. The coking output decreases with decreasing pressure in the coking chambers;
- Recycling ratio of raw materials;
- composition of raw materials;

Results
Kinetics of coking reactions
The kinetic parameters of coking and pyrolysis reactions can be determined by conducting TGA at different temperatures. Based on isoconversion methods, Schuker (1983) obtained a number of activation energies for pyrolysis depending on the evaporated part of the asphalt. At higher conversion rates, the activation energy was higher. On the other hand, Shikh and Son [3] found that the rate of conversion of activation energy is almost constant for different values.

Using the direct dependence of Arrhenius, Park, and co-authors [4], he found that the activation energy in the decomposition region of carbonaceous materials at 350–600 °C was in the range of 146–246 kJ/mol. mol. The area where the evaporation of light organic substances occurs (50-350 °C), the activation energy is less (19-23 kJ / mol). Separation of atmospheric residues

Different fractions of atmospheric distillation residues of heavy oil were isolated by chromatographic separation. The properties of the oil and the atmospheric distillation residue are given in the table.

| Property                          | Oil | atmospheric residue |
|----------------------------------|-----|---------------------|
| Density, °API                    | 12  | 5.6                 |
| Sulfur content, % by weight      | 5.29| 6.08                |
| Amount of metals mg / kg: Ni     | 89  | 97                  |
| Elemental composition, % by mass:|      |                     |
| C                                | 83.98| 82.56.              |
| H                                | 10.28| 10.56               |
| N                                | 0.40 | 0.74                |
| Ingredients, % by weight:        |     |                     |
| Saturated hydrocarbons are aromatic hydrocarbons | 15,83 | 11,75 |
| hydrocarbons                     | 36.74| 23,66               |
| resins                           | 18.61| 34,27               |
| asphaltenes                      | 28.82| 30,32               |

After separation of saturated and aromatic hydrocarbons, resins and asphaltenes, TGA was carried out for each part, as well as for atmospheric residues. The temperature was changed from room temperature to 800 °C. To determine the kinetic parameters of coke formation, all fractions and atmospheric residues (excluding saturated hydrocarbons) were analyzed at three different temperatures: 8.12 and 16 °C / min. Thermogravimetric analysis of the saturated hydrocarbon fraction was performed only at a single value of the temperature (8 °C / min) as it is prone to early thermal decomposition.

Non-isothermal kinetics
Kinetic parameters of pyrolysis of asphalts were determined by non-isothermal method. TGA data were analyzed by the Friedman method and the kinetics were calculated for the first-order reaction. The method is based on the comparison of data obtained at different linear heating rates. When the form of the kinetic equation is unknown, it can be used to find the activation energy of a number of processes. According to Shuker and Keveshan (1980), the thermal decomposition of heavy components can be described as follows

\[ A \rightarrow \alpha (koks) + (1 - \alpha)V \] (1)

where A is the reagent; V - volatile fraction; \(\alpha\) is the stcheometric coefficient for coke.

The following kinetic expression for volatile products can be obtained from this equation:

\[ \frac{1}{V_0} \frac{dV}{dt} = k_0 e^{-E_A/R_T \left[ 1 - \frac{V}{V_0} \right]} \] (2)
where $V_0$ is the total amount of evaporated substance. The linear transformation of equation (2) gives the following expression:

$$\ln \left[ \frac{dx}{dt} \right] = \ln[k_0(1-x)] - \frac{E_A}{RT} $$

(3)

where $x = \frac{V}{V_0}$ is part of the volatile fraction, corresponding to the degree of transformation of asphalts during thermal decomposition.

Equation (3) is used by substituting different values of the degree of transformation $x$ ranging from 0.1 to 0.8. The first derivatives of the TGA curves were used to determine the $dx / dt$ and $T$ values for all values of the conversion rate obtained at different temperature rates (8, 12, 16 °C / min). The linear regression of formula (3) gave a number of values of activation energy ($E$) and previous exponential factors ($k_0$) depending on the degree of conversion of the asphalts.

**Results**

**Thermal decomposition**

Figure 1 shows the results of the TGA analysis of atmospheric residues and other fractions:

- Atmospheric residue. The mass varies between 100 and 500 °C. Initially, evaporation is mainly due to the distillation of light alkanes and lasts up to 350 °C. At temperatures between 350 and 500 °C, showing the decomposition of heavy fractions - asphalt and resin rapid evaporation occurs. Evaporation between 500 and 800 °C is low and continues at an almost constant rate, with coke output from the atmospheric residue at 16.3 ms. %.

![Thermograms and curves of the rate of change of mass of atmospheric residue and its fractions when heated in nitrogen atmosphere at 80S / min](image-url)
Asphaltenes. Evaporation from room temperature to 350 °C corresponds to a conversion of almost 10%. [5] reported that changes observed at temperatures of about 350 °C could be explained by the removal of alkyl groups of asphaltene structures from peripheral areas.

The most significant mass loss is observed in the temperature range between 430 and 550 °C, where intermolecular and chemical bonds are expected to be broken, including sulfur bridges and C-C bonds. At this stage, asphaltenes can be converted into gases and valuable components, i.e., oils. As pyrolysis takes place between 550 and 800 °C, asphalt undergoes condensation reactions to form coke as a final product. In the range of 600 to 800 °C, the coke product obtained from the asphalt part remains practically stable (43.1 kt.).

- Resins. Reflecting this fraction gives a 7% mass loss in the range of 50 to 150 °C, which is light reflects the evaporation of alkanes. Distillation continues between 150 and 350 °C. Between 350 and 500 °C, mass loss is accelerated by the reactions of the cracking process. During this period, almost 80% of the resin mass is thermally decomposed. The pyrolysis interval of resins is the widest compared to other fractions. A possible explanation for this is that during pyrolysis, resins can participate in condensation reactions with the formation of heavier molecules, such as asphaltenes [6]. Weakly bound alkyl groups form free radicals that tend to neutralize and condense into larger molecules. After evaporation of most of the light compounds from the initial stages of heating, the remaining large molecules of resin and asphalt formed as a result of thickening evaporate, which explains the extent of pyrolysis of resins. Coke from resins makes up 4.6% of the mass.

- Aromatic hydrocarbons. No significant mass loss occurs at temperatures up to 100 °C. In the range of 100 to 320 °C, the most variable is the evaporation of mono-, di-, tri- and higher polycyclic compounds. In the range of 320-480 °C, resins undergo cracking reactions. Coke output is 3.8 blunt. About % of aromatic hydrocarbons are very close to resins.

  - Saturated hydrocarbons. All compounds of this fraction give very small amounts of coke (0.3 kg.%). Due to complete evaporation. Saturated hydrocarbons are practically not involved in cracking reactions: all changes occur in the distillation phase.

  - Thermograms of asphalts and atmospheric residues behave similarly at temperatures below 400 °C; Between 450 and 800 °C, it is practically the same. This may indicate that the behavior of atmospheric residues in this range is generally determined by reactions involving heavy fractions such as asphalt.

Figure 1 separately shows the rate of change in the mass of each fraction and atmospheric residue. The maximum rate of change in the mass of asphalts and resins is observed at 467 and 455 °C, respectively. The point of the maximum mass loss ratio of asphalts (467 °C) is very close to that obtained by other researchers. At relatively low temperatures (below 350 °C) the thermal decomposition of asphaltenes continues with the elimination of peripheral groups. At temperatures above 350 °C, asphalt structures are significantly reduced in size. In the early stages of pyrolysis, low-molecular compounds are distilled, but it is also possible for larger molecules to break down with the formation of volatile fragments with increasing temperature.

Initially, gases are released as a result of breaking the alkyl chains, but at fairly high temperatures (above 450 °C) the decomposition of asphalts breaks stronger chemical bonds and breaks down skeletons, increasing the amount of gases released.

![Table 2. Values of activation energy and exponential stress depending on the degree of conversion](image)

| X  | Atmospheric residue | Asphaltenes | Resins | Aromatic hydrocarbons |
|----|---------------------|-------------|--------|-----------------------|
|    | E_A (kJ/mol) | k_0 (kJ/mol) | r     | E_A (kJ/mol) | k_0 (kJ/mol) | r     | E_A (kJ/mol) | k_0 (kJ/mol) | r     |
| 0.1 | 4.10^5 | 1.410^4 | 0.989 | 4.10^4 | 0.978 | 0.992 | 1.410^4 | 0.978 | 0.992 |
| 0.2 | 4.410^6 | 1.810^8 | 0.999 | 5.910^9 | 0.998 | 0.998 | 7.810^9 | 0.997 | 0.997 |
| 0.3 | 1.010^7 | 4.210^8 | 0.995 | 3.910^7 | 0.996 | 0.999 | 1.710^7 | 0.991 | 0.991 |
| 0.4 | 4.810^4 | 1.610^7 | 0.991 | 5.310^12 | 0.993 | 0.999 | 1.310^12 | 0.999 | 0.999 |
| 0.5 | 9.510^6 | 6.710^8 | 0.985 | 5.210^15 | 0.995 | 0.996 | 1.210^15 | 0.996 | 0.996 |
| 0.6 | 2.410^6 | 4.610^6 | 0.994 | 4.910^16 | 0.998 | 0.998 | 1.310^16 | 0.998 | 0.998 |
| 0.7 | 2.710^9 | 5.910^16 | 0.999 | 4.710^15 | 0.997 | 0.994 | 1.710^15 | 0.994 | 0.994 |
| 0.8 | 2.410^8 | 8.10^17 | 0.987 | 2.610^15 | 0.999 | 0.999 | 2.610^15 | 0.999 | 0.999 |

Philadelphia, USA 39
The most significant conversion of asphalts occurs in the range of approximately 430 to 550 °C. Compared to atmospheric residues and other fractions, this is the narrowest range in which fission reactions predominate. Coke yield was the same at all temperatures (43.1% by weight) and the activation energy increased to peak values at the conversion levels of 0.5 and 0.8. Asphalt has a higher activation energy than atmospheric residues and other fractions can be associated with free radicals in the reaction fracture operations.

Atmospheric residue is formed by the distillation of lighter components, resulting in the concentration of heavy components in heavy fractions; The only significant reaction to cracking under these conditions.

Evaporation of the resins is completed at about 500 °C. The coke output is the same at all three values of heating rate (4.6 kg.%). With the increase in the conversion rate, the activation energy changes and reaches the highest values between 0.4 and 0.8. This process can be the result of the decomposition of resins with the formation of free radicals condensing in the form of coke.

The evaporation curve and the Arrhenius area for aromatic hydrocarbons are not shown; for them only the values of the activation energy, the pre-reading factor and the correlation coefficient are given in Table 2. The activation energy of this fraction is less than that of asphalt and resins; is approximately the same as atmospheric residues at low conversion rates. Thermogravimetric data show that asphalts contribute the most to the formation of odors; they are followed by resins and aromatic hydrocarbons. In terms of activation energy, the atmospheric residue occupies an intermediate position between aromatic hydrocarbons and resins.

**RESULTS**

The results show that asphalt is the main coke-forming part. It accounted for 43.1% of the asphalt coke mass. Decomposition reactions should be expected to convert asphalts to gases, oils and resins. Resins and aromatic hydrocarbons produce almost the same amount of coke, but the activation energy of resins is slightly higher. Saturated hydrocarbons evaporate almost completely. Atmospheric residue indicates that the activation energy increases with increasing conversion rate. This indicates that in the first stages of heating, the light components evaporate, and then the heavy fractions - resins and asphalts - begin to break down.
10. Shixaliyev. K. (2020). Properties of Linear Low Density Polyethylene.Amirov Fariz.Shixaliyev Kerem. International Journal of Innovative Technology and Exploring Engineering (IJITEE). Volume-9 Issue-9, July 2020, pp. 348-352. ISSN: 2278-3075. SCOPUS https://www.ijitee.org/download/volume-9-issue-3/

11. Shixaliyev. K. (2020). Paint and Varnish Materials Based on Epoxy Novolac Oligomers Jour of Adv Research in Dynamical & Control Systems. Vol. 12, Special Issue-02, 2020, pp.351-358.
ISSUES OF ENSURING THE OPERABILITY OF THE MECHANISM FOR CHANGING THE BASE OF A FOUR-WHEEL TRACTOR

Abstract: The growth of the share of mechanization in the total volume of field work in mountainous and foothill areas or on hilly terrain with areas with significant irregularities and slopes is constrained by insufficient longitudinal and lateral stability of serial tractors. To solve this problem, "CTCAE" RLO has begun work on the development of a tractor with a variable track and base. During field and transport work on areas with significant irregularities and slopes where stability is required, the base of this tractor is set to the greatest. At the same time, for processing relatively flat and small areas where a minimum turning radius is required, on the contrary, its base is set to the smallest. The transfer of the tractor from one base to another is carried out by the mechanism of changing the tractor base. Reliability of work, which largely depends on the parameters of its most critical units and parts that are correctly selected when constructing. The conducted studies have shown that the proposed method for checking the reliability of the hydraulic cylinder axis is also acceptable for checking the reliability of the remaining axles of the mechanism for changing the base of the tractor. In the course of the study, it was found that the parameters incorporated in the design of the axis of the hydraulic cylinder withstand the load applied during the operation of the mechanism for changing the base of the tractor and provides the condition of strength in the dangerous section, that is, \( \sigma \leq [\sigma] \), therefore, the mechanism is operational.

Key words: tractor, front beam, bar, spar, mechanism, base, track, parts, hinge, hydraulic cylinder, load, slope, stability, controllability.

Language: Russian

Citation: Akhmetov, A. A., Karimov, A. K., Kambarova, D. U., & Begmatov, D. K. (2021). Issues of ensuring the operability of the mechanism for changing the base of a four-wheel tractor. ISJ Theoretical & Applied Science, 03(95), 42-47.

Doi: https://dx.doi.org/10.15863/TAS.2200.
Аннотация: Рост доли механизации в общем объеме полевых работ на горных и предгорных районах или на холмистой местности, имеющие участки со значительными неровностями и склонами, сдерживается из-за недостаточной продольной и поперечной устойчивости серийных тракторов. Для решения этой проблемы в ООО «КТЦСМ» начаты работы по разработке трактора с изменяемой колеей и базой. При полевых и транспортных работах на участках со значительными неровностями и склонами, где требуется обеспечение устойчивости, база у этого трактора устанавливается наибольшим. В то же время для обработки сравнительно ровных и малых участков, где требуется минимальный радиус поворота, наоборот, его база устанавливается наименьшим. Перевод трактора с одной базы на другую осуществляется механизмом изменения базы трактора. Надежность работы, которого во многом за- висит от правильно выбранных при конструировании параметров его наиболее ответственных узлов и деталей. Проведенные исследования показали, что предложенная методика проверки надежности работы гидроцилиндра приемлемо и для проверки надежности остальных осей механизма изменения базы трактора. В ходе исследований установлено, что параметры, заложенные в конструкцию оси гидроцилиндра, выдерживают нагрузку, приложенную во время работы механизма изменения базы трактора, и обеспечивают условию прочности в опасном сечении, то есть \( \sigma > [\sigma] \), следовательно, механизм работоспособен.

Ключевые слова: трактор, передняя балка, брус, лонжерон, механизм, база, колея, детали, шарнир, гидроцилиндр, нагруженность, уклон, устойчивость, управляемость.

Введение

УДК 629.114.2

В подавляющем большинстве технологических операций по возделыванию сельскохозяйственных культур применяются универсально-пропашные тракторы[1-3]. При этом достигаются полноценного использования технико-эксплуатационных показателей этих тракторов, работает из-за отсутствия возможности изменения их базы.

Например, рост доли механизации в общем объеме полевых работ на горных и предгорных районах на холмистой местности, имеющих участки со значительными неровностями и склонами, сдерживается из-за недостаточной продольной и поперечной устойчивости серийных тракторов. Если поперечная устойчивость определяется колеей трактора, то продольная – его базой [4].

С точки зрения продольной и поперечной устойчивости, а также устойчивости движения более благоприятна и безопасно работа с машинотракторными агрегатами, составленными на базе тракторов с большей колеей, удлиненной базой и низким расположением центра тяжести [5]. Поэтому при работе на неровных, холмистых участках для обеспечения устойчивости трактора его база и колея должна быть наибольшим. В то же время для обработки междурядий культур, возделываемых в этих регионах, для обеспечения минимального радиуса поворота, наоборот, база трактора должна быть наименьшим. Однако серийные универсально-пропашные тракторы, выпускаемые отечественными производителями, не имеют такой возможности. Для устранения этого недостатка серийных тракторов в ООО «Конструкторский технологический центр сельскохозяйственного машиностроения» (КТЦСМ) разработан трактор с изменяемой базой [6] под условной маркой ТТЗ-1080 (рис. 1).

Рис.1. Трактор с изменяемой базой ТТЗ-1080 при: а - удлиненной базе; б – укороченной базе
Цель исследования – проверка надежности наиболее ответственных деталей механизма изменения базы и перевода трактора с меньшей базы на большую базу и обратно.

Материалы и методы. В отличие от серийных тракторов разработанный в КТЦСМ трактор снабжен механизмом изменения базы трактора (рис. 2).

Рис. 2. Механизм изменения базы трактора

Механизм изменения базы трактора представляет собой параллелограммный механизм, вмонтированный между лонжероном 7 и бруском 11 полурамы соединенной посредством оси 13 с балкой 1 переднего моста с направляющими колесами 2 трактора. Шарнирно соединенный между собой лонжерон 7, брус 11, передние 12 и задние 5 звенья представляют собой параллелограммный механизм.

Механизма изменения базы приводится в действие силовым гидроцилиндром 6, который принудительно поворачивает передние звенья 12 параллелограммного механизма вокруг шарнира. Поворот передних звеньев приводит к изменению положения всех 5 и 12 звеньев параллелограммного механизма, следовательно, балки 1 переднего моста трактора. При принудительном выдвижении штока 4 гидроцилиндра 6 производится наращивание базы трактора, если шток задвигается – уменьшение базы. Как показали замеры, максимальное приращение при этом базы трактора составляет 673 мм.

При необходимости увеличения длины базы трактора с помощью гидроцилиндра 6 шток 4 выталкивается в наружном направлении. В свою очередь шток посредством шарнира 3 поворачивает закрепленный с ним звенья 12 и, тем самым, перемещает шарнирно связанный с передними 12 и задними 5 звеньями брус 11 полурамы вперед до тех пор, пока он не упирается в упор 10. Положение бруса 11 полурамы после оперения в упор 10 фиксируется фиксатором 9. Такое перемещение относительно лонжерона 7 бруса 11 полурамы вперед увеличивает длину базы трактора, и она будет максимальной.

Для уменьшения длины базы трактора шток 4 втягивает внутрь гидроцилиндра 6. При этом связанный штоком шарнир 3 поворачивает закрепленный с ним звено 12, перемещает шарнирно связанной с передними 12 и задними 5 звеньями брус 11 полурамы назад до тех пор, пока он не упирается в упор 8. Положение 11 полурамы после оперения в упор 8 фиксируется фиксатором 9. Такое перемещение относительно лонжерона 7 бруса 11 полурамы назад уменьшает длину базы трактора, и она будет минимальной.
Результаты и обсуждение. Компактность и безотказность работы этого механизма во многом зависит от правильно подобраных конструктивных параметров наиболее нагруженных деталей механизма изменения базы трактора.

У механизма изменения базы все подвижные элементы: передние и задние звенья, кронштейн и гидроцилиндр посажены на оси. Каждый из передних звеньев выполнено с тремя проушинами, куда посредством втулки вставляются оси. В среднюю проушину вставляется ось гидроцилиндра, а верхнюю и нижнюю проушину - верхняя и нижняя оси механизма изменения базы трактора.

Среди них наиболее нагруженными является ось гидроцилиндра (рис. 3), который обеспечивает передачу толкающего усилия к двум ведущим - передним звеньям механизма изменения базы трактора. Поэтому методику проверки надежности работы осей проводим на примере оси гидроцилиндра.

Для оценки прочности оси гидроцилиндра механизма изменение базы приняты классические методы механики, применяемые для расчета и оценки прочностных показателей деталей[7, 8]. Опираясь на конструктивные параметры, заложенные при первичной комплектации в конструкцию, а также на действующие во время работы на оси усилия (табл.1) определяем прочностные показатели осей механизма изменения базы трактора.

Таблица 1. Исходные данные

| Наименование показателей | Значение |
|--------------------------|----------|
| Колесная формула         | 4К2      |
| Толкающее усилие гидроцилиндра Ц100 $F_{ун}$, Н | 123213 |
| Усилие $F_{10м}$, Н     | 42840    |
| Усилие $F_{21}$, Н      | 89702    |
| Диаметр оси $d$, мм     | 40       |
| Материал                | 40Х ГОСТ4543 |
| Твердость               | 37…42 HRC, |
| Предел текучести $\sigma_{\text{тк}}$, МПа | 882,9    |
Предварительный силовой анализ [9] показывает, что на ось действует изгибающий момент.

Усилия в опорах A и B, определенные согласно расчетной схеме (рис. 4) будут

$$R_A = R_B = 0,5F_w = 61606,5 \text{ Н.} \quad (1)$$

Напряжение изгиба при действии толкающего усилия гидроцилиндра

$$\sigma_u = \frac{M_{\text{max}}}{W_x}, \quad (2)$$

где $M_{\text{max}}$ – максимальный изгибающий момент; $W_x$ – момент сопротивления изгибу поперечного сечения оси.

Рис. 4. Расчетная схема

Допускаемый запас прочности по пределу текучести определяется выражением [10]

$$[n]_p = n_1 \cdot n_2 \cdot n_3, \quad (6)$$

где $n_1$ – основной коэффициент запаса, учитывающий отклонение механических характеристик от нормативных вследствие нарушения технологии изготовления, наличия остаточных напряжений, значение которого по предельным нагрузкам для поковки составляет $n_1 = 1,2$, а для литья $n_1 = 1,5$;

$n_2$ – коэффициент запаса, учитывающий точность определения расчетных нагрузок и напряжений, $n_2 = 1,4$;

$n_3$ – коэффициент запаса, учитывающий ответственность детали, $n_3 = 1,2$.

Подставляя числовые значения в (6), получим

$$[n]_p = 1,2 \cdot 1,4 \cdot 1,2 = 2;$$

тогда

$$[\sigma]_{40X} = 441,45 \text{ МПа.}$$

Результаты проведенного расчета показали (таблица 2) то, что, несмотря на изящность конструкции при выполнении оси гидроцилиндра с диаметром 40 мм условие прочности не выполняется, следовательно, ось не работоспособна.
Таблица 2

| $M_{\text{max}}$, Нмм | $W_x$, мм$^3$ | $\sigma$, МПа | $[\sigma]_T$, МПа |
|----------------------|--------------|--------------|-----------------|
| 7392780              | 6283,2       | 1176,6       | 441,45          |

Рекомендуется увеличить диаметр посадочного места крепления штока гидроцилиндра с $d=40$ мм до 50 мм и обеспечить закалку до твердости 46…51 HRC, на указанном участке $A$.

Как показали результаты предварительного расчета опасного сечения при выполнении предложенных рекомендаций (таблица 3), условия прочности выполняются, следовательно, ось гидроцилиндра работоспособна и выдерживает приложенную во время работы механизма нагрузку.

Таблица 3

| $M_{\text{max}}$, кгс мм | $W_x$, мм$^3$ | $\sigma$, МПа | $[\sigma]_T$, МПа |
|-------------------------|--------------|--------------|-----------------|
| 7392780                 | 12272        | 602,41       | 637,65          |

Предложенная методика проверки прочности оси гидроцилиндра приемлема для проверки прочности и других осей механизма изменения базы трактора.

Выводы.

Таким образом, при работе ось гидроцилиндра испытывает нагрузку, вызывающую изгибающий момент в 7392780 Нмм, откорректированные параметры, заложенные в конструкцию оси гидроцилиндра, выдерживает максимальный изгибающий момент, и обеспечивает условию прочности в опасном сечении, то есть $\sigma>[\sigma]_T$, следовательно, механизм работоспособен и выдерживает приложенную во время работы механизма изменения базы трактора нагрузку.

References:

1. (2012). Sistemamashin i texnologiy dlya kompleksnoy mekanizatsii selskhozoyastvennogo proizvodstvana 2011-2016 gg. – Ch. 1, rasteniyevodstvo. (p.199). Tashkent: NPS pri MSVX RUz.
2. Gurevich, A.M. (1983). Traktori i avtomobili. (p.336). Moscow: Kolos.
3. (1988). Traktori: Teoriya: Uchebnik dlya studentov vuzov posp. «Avtomobili i traktori» / V.V. Gusikov, N.N. Velev, Y.E. Atamanov i dr.; pod obsh.red. V.V. Gusikova. (p.376). Moscow: Mashinostroyeniyie.
4. Anilovich, V.Y., & Vodolajchenko, Y.T. (1976). Konstruirovanie i raschet selskhozoyastvennix traktorov. (p.456). Moscow: Mashinostroyeniyie.
5. Smirnov, G.A. (1990). Teoriya dvijeniya kolesnih mashin. (p.352). Moscow: Mashinostroyeniyie.
6. Axmetov, A.A., Usmanov, I.I., & Asamov, S. (2017). Vibor konstruktsii universalnoprashnogo traktora s izmenyayusheysya bazoy. FarPI ITJ, 2017 y., Tom 21, №2, pp.132-135.
7. Rayko, M.V. (1966). Raschetdetaley i uzlov mashin. (p.498). Kiyev: Teknika.
8. Pisarenko, G.S. (1975). Spravochnik posoprotivleniyu materialov. (p.704). Kiyev: Naukovadumka.
9. Axmetov, A.A., & Usmanov, I.I. (2016). Opredeleniye silashtoke gidrotsilindra mekanizmaizmeneniyi bazit raktora v nachalnyj moment umensheniya dlini bazi. Gorniyvestnik, №4(№67), pp. 78-80.
10. Rozovskiy, M.S. (1976). Opredeleniye zapasov prochnosti i dopuskayemix napryahenyi. (p.55). Moscow: NIItraktorolxozmash.