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EDITORIAL

CHEMISTRY AND LABORATORY WORK

Temechegn Engida
Email: temechegn@gmail.com

Dear AJCE Communities,

I hope you all agree that laboratory work needs to be an integral component of the study of Chemistry, theoretically speaking at all levels of the education system. In fact many argue that Chemistry is an experimental science.

In practice, however, there are many challenges in engaging students in chemistry laboratory work, particularly in less developed countries. Lack of budget in equipping the labs, constrains in foreign currency to purchase genuine chemicals, lack of trained personnel to handle and maintain the equipment, overemphasis of classroom and national Chemistry exams on mere theory (at the expense of practical/process skills), the way chemistry lab activities and organized and carried out (like as mere theory verification means and highly structured—cookbook approach) are some of the challenges.

In response to these challenges, the authors of this issue of AJCE are dwelling on various strategies. Whereas John Bradley looks at microscale chemistry, Hans-Dieter Barke and Nina Harsch say goodbye to the “laboratory jargon” revolving around acid-base theories. On the other hand, whereas Sintayehu Leshe deals with developing and implementing assessment moderation procedures to evaluate written laboratory reports, Zewdu Bezu and his co-authors look at improving the implementation of pre-laboratory flow charts, cooperative learning and laboratory report writing in first year Organic Chemistry I laboratory class.

I hope you will enjoy reading them all!

SJIF IMPACT FACTOR EVALUATION [SJIF 2012 = 3.963]
ACHIEVING THE AIMS OF SCHOOL PRACTICAL WORK WITH MICROCHEMISTRY

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ABSTRACT

“Chemistry is fundamentally an experimental subject…education in chemistry must have an ineluctable experimental component”.

This quote from an IUPAC report reflects a core belief of all chemistry educators. However we must define our aims for practical activities, and design and prepare for them in the context of national curricula. All this is necessary whatever the scale (macro or micro) of equipment that might be employed. At the present time traditional macroscale equipment dominates the school scene and penetration of microscale use is slow. This dominance is not because there are no problems with the status quo; quite the opposite. Most schools have no equipment at all or, if they have some, never use it. This despite national curricula explicitly encouraging practical science activities. Based primarily upon the experiences of our group in South Africa, this paper addresses the following questions:

1. what are the aims of school practical work?
2. can microscale chemistry deliver as well as, or better than, macroscale?
3. why is practical work (macro or micro) problematic in schools?
4. can microchemistry ameliorate these problems?
5. could recognition of the concept of Zone of Feasible Innovation help us?

Microchemistry has so much to offer school chemistry, that answering these questions and acting accordingly should be a priority. [African Journal of Chemical Education—AJCE 6(1), January 2016]
INTRODUCTION

“Chemistry is fundamentally an experimental subject...education in chemistry must have an ineluctable experimental component.”[1]

The IUPAC quote is one of a number of similar affirmations that practical activities are an inescapable part of chemistry education. Most chemistry educators at all levels share this view, and national school curricula express the same view at least by implication. Yet there is a steady rumble from doubting administrators and researchers, who question what evidence we have for our beliefs [2]. Indeed the World Bank some years ago decided that investing in laboratories for schools in developing countries was such poor value for money that it would be discontinued [3]. Despite these serious contrary views, other important organizations like UNESCO, have continued to try to promote practical science in schools. Over decades, they have supported projects devoted to improvisation, to low-cost, locally-produced equipment and, in the most recent period, to the Global Microscience Project – a project in which we have participated for several years [4].

Located as our group is in South Africa, the UNESCO – promoted call for Education for All is one which has strong appeal for us [5]. We see the Global Microscience Project as an important element in achieving education for all. We understand that education for all must include science education for all, and ineluctably there must therefore be practical science education for all. In our view there is no other way of achieving this except by low-cost, microscale science.

Twenty years after the start of the Global Microscience Project, it is appropriate to take stock of how far we are along this developmental road and to look ahead to see how best to reach the goal of practical science education for all.
WHAT ARE THE AIMS OF SCHOOL PRACTICAL WORK?

So what are the desired outcomes of practical work in science education? Scores of educational experts have proposed lists expressed in sufficiently general terms that they should be applicable around the World, whatever the national curriculum and the science subject. Woolnough and Allsop [6] have a brief listing that is useful and has wide support:

1. Motivation
2. Developing Practical Skills
3. Learning the Scientific Approach
4. Gaining a Better Understanding of Theoretical Aspects of the Subject

Criticisms of the investment in practical work are not about the worth of these aims, but about the lack of sound evidence that they are achieved. In part this may be due to the fact that most national examination systems depend heavily upon written testing of “theory” or factual content of the curriculum. Awareness of this has a massive influence on what teachers do; they teach as best they can towards the success of their learners in those exams and think that relentless emphasis on drill and practice is the right method. They do not believe that the fourth aim of Woolnough and Allsop (gaining a better understanding of theoretical aspects of the subject) is achievable through practical work, failing to acknowledge the educational implications of the fact that, historically, theory grew out of experiment. They see practical work rather as a separate and additional task that takes up valuable time that would be better spent on simply telling learners what they must learn.
WHY IS PRACTICAL WORK PROBLEMATIC IN SCHOOLS?

Some problems have already been mentioned, and we can add others which are familiar:

- aims often confused and unfocused;
- emphasis on achievement in written exams;
- insufficient time in the curriculum;
- poor quality/inexperience of some teachers;
- inadequate or no technical assistance;
- cost too great for what it could achieve;
- safety and environmental regulations limit scope.

All of these have been long-standing complaints around the World, and by implication they inhibit practical work of any scale. Universal education/Science for All has exacerbated these problems because the burden of numbers acts against individual hands-on activities. The cost burden weighs more heavily also, as do the concerns for safety and environmental impact. In poorer countries all these issues tend to be magnified, as Kahn [7] and Lewin [8] have described.

So, one needs to realize that practical work in schools is challenged by a number of problems, and these have to be faced whether macro or micro is your scale. Yet we still have this widespread belief that practical work is important, and we think there are sound aims to strive for through this activity. So it is not an option to give up, nor is it an answer to say we can achieve the aims virtually (although virtual support can assist) [9]. What evidence can we find to be able to recommend microscale chemistry to teachers and educational planners?
**CAN MICROSCALE CHEMISTRY DELIVER ON THE AIMS AS WELL AS, OR BETTER THAN, MACROSCALE?**

Motivation is a potent outcome because it can feed into all aspects of learning. We have gained evidence from our experiences in South Africa, a developing country, that practical work is enthusiastically enjoyed by most learners, and with microscale equipment this outcome is certainly no less successful than with traditional equipment. For such learners the novelty of hands-on activities may enhance the impact recorded in more developed countries, but everywhere the effect is qualitatively similar. Girls seem to particularly express enthusiasm, perhaps related to a sense of greater safety with microscale activities. But we have also seen that where the teacher is poorly prepared or incompetent, there is no motivation, so the hands-on activities at whatever scale must be appropriately managed.

As for the gaining of a better understanding, we have been able to make direct comparisons in certain cases: for example, Sebuyira found that those doing the microscale version of a particular activity, achieve somewhat better than those doing the macroscale [10]. This, despite the fact that the students state it is more difficult to see things on microscale! I think we have learned that “more difficult” does not mean a problem, but rather that close attention is required – and that is an advantage.

Developing of practical skills is an aim that is interpreted by some in a very limited sense. They think only of the handling of traditional equipment, and cannot imagine how microscale equipment can possibly fulfill the aim. However in my mind this is not the intention of Woolnough and Allsop, and other similar authors. They know very well that no school can provide experience of a wide range of science equipment. It is not the specifics of particular items such as test tubes and burettes, but the considerations and techniques that go into how they are used. Glass is a very
robust material insofar as chemical attack is concerned; there are good reasons why it is the material of choice for most professional laboratories. But it comes at a price and is rather easily broken – even one might say, dangerously so. Plastics are today more the common experience than glass, and learning to exploit their good properties and avoid the poor ones is a useful life skill. Similarly, although today they build bigger cruise ships and bigger bridges, these are not for individuals: these are for our growing population. For individuals the trend is opposite, towards miniaturization – above all exemplified in the all-pervasive cell phones, etc. So for hands-on use, small has become the norm and this is the same trend evident in doing practical chemistry [11]. What matters is choosing the right tools for the job, taking care of the tools, appreciating that observations may be qualitative or quantitative, and understanding significant figures.

Which brings us to the aim of learning the scientific approach. This aim requires not only practical skills but meaningful interplay between theory and observation. This should not be interpreted as just confirming an already established theory. It means applying a theory in practice, seeing whether or not it works whilst guarding against prejudice, suggesting alternative ways of thinking, thinking of logical extensions, planning a new experiment, etc. In other words, not just busy work, but thoughtful work. This kind of scenario is rarely played out in a school classroom, but lies at the heart of the movement for inquiry-based science education. Lamba [12] puts this emphatically as inquiry-based, student-centred instruction, and reports consistent, significant learning achievement gains. There is no evidence of differences between macro and microscale in this context, but we may reasonably expect that there are big advantages to microscale.
CAN MICROCHEMISTRY AMELIORATE THE PROBLEMS OF SCHOOL PRACTICAL WORK?

If microchemistry can be at least as successful as traditional scale chemistry in achieving the aims of practical work, does it offer advantages in regard to the wider contextual problems faced by practical work in schools? I think there are indeed three features of microchemistry that can help.

Low-cost: The cost advantage of microscale chemistry needs no argument. If we use a figure like 10% of traditional, then this means that 10 times as many learners and/or experiments could be done with the same budget as traditional scale. And this is just initial cost. Taking into account consumables this advantage is amplified, partly because plastic equipment is not so breakable. So Lamba’s inquiry-based, student-centred instruction becomes a whole lot more feasible! Furthermore, development of learner-centred teaching, (a threatening prospect for many teachers!), can be facilitated in a natural way when hands-on practical activities are introduced.

Safety & environment: The heightened interest we all have in safety and in pollution is appropriate in an increasingly crowded World. There is no question that both these problems are greatly reduced on microscale. Furthermore the continued use of excessive volumes of chemicals sends the wrong message as regards the attitudes of chemists. Whilst everyone around the World is working towards using less energy, and engineers are working day and night to reduce fuel consumption, are chemistry teachers going to be the glaring exception in resource consumption? [13]. Using microchemistry it is also no longer necessary to limit practical chemistry to a laboratory; of course care is required. But then care is always required, whether in or out of a laboratory and all the rules of good practice apply regardless of location. So this now becomes learning a life skill rather than just a laboratory skill. When science budgets for school systems...
can be relieved of laboratory building and maintenance, they will look much more palatable. Mobile laboratories have often been touted as a way of spreading scarce traditional resources and reducing the cost burden of building laboratories; the portability of microscale resources (equipment and chemicals) means that mobility is built in and no laboratories are needed at all.

**Easy use/convenience:** Most novices feel more comfortable with microchemistry than macrochemistry activities. Other than a small number of physically challenged there is no reason and no evidence to support claims that microscale is too small for ease of handling. Older chemistry teachers who envisage such problems are only expressing their own sense of uncertainty in the face of innovation. This is like the familiar distinction between the old and the young as regards cell phones and electronic gadgetry. It is consistent with the easy use and convenience that it is frequently reported that experiments are significantly quicker on microscale. This helps the motivation and permits classroom time for the discussion and reflection needed to gain that better understanding.

There are many potential consequences for chemistry teaching and learning in these three simple characteristics. It is not just that microscale equipment can substitute for traditional scale. Taken together they can liberate chemistry teaching from a number of restraints and limitations and open the way for methods of teaching that science education experts advocate. In brief they make feasible the inquiry-based, learner-centered style now seen as our best hope for the future of chemistry! [12] [14]

It remains important to express our convictions in terms that capture the interest of decision-makers, such as Ministries of Education. Here the “trinity of the 3 Es”, identified by Kahn [7], provides an appropriate framework:

- Equity: speaks to even-handed provision for all (EFA)
• Efficiency: refers to the cost devoted to achieving the aims

• Effectiveness: refers to the extent to which aims are achieved.

Microscale chemistry is recommended above macroscale on all three counts!

CAN THE CONCEPT OF ZONE OF FEASIBLE INNOVATION (ZFI) HELP US?

Reflecting on the numerous advantages that microscale chemistry has over macroscale chemistry, it is perhaps surprising and disappointing that the trend from macro is not more marked within the school systems around the World. There is such a trend (as Beasley and Chant asserted several years ago [11]), but in general in school systems progress has been slow. To be sure there is evidence for example that introductory workshops sponsored by UNESCO have left a trace but the gestation period is remarkably long. This may be illustrated by the case of Guyana. A UNESCO-sponsored introductory workshop on microchemistry took place in Georgetown in 2000 but it was only quite recently (2014) that a report appeared, showing that the little seed sown more than a decade earlier had germinated, and that the Ministry of Education had slowly prepared the ground for a pilot project, and then a wider implementation [15]. They solicited donor support and ordered a significant quantity of equipment from the manufacturers of RADMASTE microscience kits last year and another order is likely to be placed this year. They are evidently pleased with the outcomes. UNESCO has publicized the development in its own publications and reports, and the tone of these reports shows they are also extremely impressed and pleased.

The table shows the African national experience with microscience since UNESCO-sponsored activities started in 1998.
The African National Experience with Microscience

<table>
<thead>
<tr>
<th>Country</th>
<th>Introductory Activity</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya</td>
<td>1998</td>
<td>Univ of Nairobi and KNAS promotion over several years; AAS/OCD round-table 2013 recommends to MoE.</td>
</tr>
<tr>
<td>Tanzania</td>
<td>1999</td>
<td>National tender for kits and training for 180 schools won by RADMASTE; implemented 2011-12; UNESCO evaluation report due soon.</td>
</tr>
<tr>
<td>Angola</td>
<td>2003</td>
<td>National training 2008; signs of intent to follow up.</td>
</tr>
</tbody>
</table>

NB. This table records information we have on national-level actions/inactions and does not record efforts of various individual educators to promote and research the microscience concept.

Although this table shows some encouraging developments, it should be borne in mind that more than 40 countries in Africa hosted introductory workshops sponsored by UNESCO since 1996. In most cases there has been no known national development subsequently. Follow-up on introductory workshops is what has mostly been lacking, and progress depends absolutely on the chance that somebody with influence is convinced and determined. This was the fortunate case in Cameroon.

A similar low probability of longer-term impact attends the occasional opportunities presented by such events as the International Year of Chemistry (IYC 2011), with its Global Water Experiment. It was evident to us that despite all the hype and noise leading up to this admirable project, that much of the World’s population would not be able to participate. These unfortunate
children in poorer countries had neither equipment nor chemicals and often teachers who could not access the internet to get guidance either. We motivated to UNESCO and IUPAC that here was an opportunity to do some global good by sponsoring a special pack of microchemistry equipment for schools in such circumstances. In the end this was undertaken and 32 less-developed countries received school packs for 5 schools so that they could participate in the Global Water Experiment [16]. We know the outcome from a few such school packs but mostly there has been no feedback even though UNESCO has representation in each country. Yet again therefore one feels that an innovative idea was let go through lack of follow-up.

The message for us all is loud and clear. If we want to see our innovations making appropriate impact, we have to live long and be very determined! This glacial progress reflects mostly upon the normal pace of government implementation of innovations.

Where government makes a commitment to a pilot project, they also need to be sensitive to the situation in which they may be trying to promote the innovation. This is the central idea located within the ZFI concept. The success and uptake of any innovation depends upon several factors and one must take these into account or most likely die disappointed! The ZFI concept has been introduced by Rogan and Grayson [17] with several propositions (paraphrased below) regarding success:

1. Innovation should be just slightly ahead of existing practice.

2. Capacity to support innovation needs to be developed concurrently.

3. Outside support should not exceed the capacity of a school to use it.

4. All role players need an opportunity to re-conceptualize intended changes in their own terms and for their own context.
5. Changing teaching and learning practices should be seen as a culture change, not just a technical change.

6. The ultimate aim must always be an improved learning experience.

If we believe in these propositions, we can see why we have problems in our microchemistry mission! Our experience within South Africa, for example, is sobering. When our RADMASTE kits were made known locally, there was great interest: corporate donors were eager to buy kits for schools they supported. Many hundreds of kits were distributed and the media exploited for publicity. Government agencies, national and provincial departments of education were also excited and invested in the kits for schools on a substantial scale. Some provincial departments took the trouble to follow up after several months, and found that many kits were never used, many kits were already lacking components or had not been maintained, and only a limited percentage were actively and consistently in use [18] [19]. It must be noted that sponsors often provided for very limited teacher training only; after a one afternoon workshop teachers were truly excited until they got back to school! Most of the teachers and schools involved would have found the innovation a completely new experience and the projects predictably failed at proposition 1!

At a later stage more effort was put into teacher training, and in a quite major national project implementation the district subject specialists were themselves very much involved. But again, when everyone (400 teachers!) went back to their schools little or nothing happened – and the subject specialists who were to support them rarely visited [20].

These experiences not only wasted a lot of money; they were interpreted by some to mean that microscience is no good! For workers to blame their tools for failure is of course a familiar excuse.
We do not really know how things stand now in South Africa. Practical work in school science is still very weak; we have been told that probably more microscale chemistry is practiced hands-on than traditional scale, but cannot verify this. We continue to get requests for kits, but government tenders normally specify traditional equipment (and serve the needs of a minority of schools).

So let us learn from this depressing experience and think about the way forward with the aid of the ZFI. Consider two rather extreme situations; one perhaps typical of a poor country and one typical of a relatively richer country. Both situations are however, very likely to occur within one country.

In the poorer country, proposition one represents an impossible demand because practical work is not part of existing practice! There is a need for nucleation (to use the term associated with creating a new state or phase of matter) which requires a strongly focused project located in the best possible schools (but not the exceptional ones who already have everything however). Even with such schools the outside support must be strong, continuing and sympathetic. Initial experience with the innovation must be good, and sufficiently so that there is courage to try more. Motivation is the one aim above all that should be stressed as achievable for such teachers, and in addition the learning of practical skills.

In the richer country, schools are probably already committed to practical work, and innovation has different implications. The teacher most likely sees that practical work is necessary but perhaps follows existing routines rather thoughtlessly. Such a teacher could be open to a culture change where hands-on practical activities generate more motivation by virtue of their integration into an inquiry-based approach to science education. However, a lot of thought has to go into how this will be done, and the old familiar issue of focusing on a written exam will have to be
confronted sympathetically. In this situation, the aim of gaining a better understanding of theoretical aspects of the subject (chemistry) can be made emphatically by reference to evidence of how suitably-designed practical activities can facilitate conceptual change and correction of misconceptions [21]. Similarly, learning the scientific approach could be emphasized within the framework of an inquiry-based, learner-centred teaching and learning of chemistry.

CONCLUSION

We continue to learn as we go forward with microchemistry and continue to believe that most of its potential benefits for chemistry education have yet to be realized. We admire and are thankful for the persistence and vision of UNESCO and others in this cause [22]. And we draw strength from the foreword to the recent book (2015) - Chemistry Education: Best Practices, Opportunities and Trends – in which Peter Atkins [23] writes:

> Crucial to this endeavour (chemistry education) is the demonstration that the concepts and calculations of chemistry relate to actual physical phenomena (or should) and that experiment and observation, not ungrounded algebra, lie at the heart of science. The contributions acknowledge this core feature of science, and although microscale experiments, which are discussed here, are not to everyone’s taste, they are far better than unsupported printed assertion and unadorned abstraction.

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DONOR-ACCEPTOR REACTIONS:
GOOD BYE TO THE LABORATORY JARGON

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ABSTRACT
For chemistry education we are discussing mainly two concepts of acids and bases: theories
of Arrhenius and Broensted. The first theory discusses the dissociation of molecules into ions:
hydrochloric acid solution contains H\(^+\) (aq) ions and Cl\(^-\) (aq) ions, sodium hydroxide solution
contains Na\(^+\) (aq) ions and OH\(^-\) (aq) ions. This theory therefore deals with substances, which are
acids or bases – it would be even better to take the logical names ”acidic and alkaline solutions”.
If both solutions are mixed in equivalent quantities, the H\(^+\) (aq) ions react with OH\(^-\) (aq) ions to
form H\(_2\)O molecules, while the other ions remain in solution. The Broensted theory defines
protolysis and proton transfers: a molecule or an ion transfers a proton (H\(^+\) ion) to another
molecule or ion; two conjugated acid-base pairs are involved. Thus, Broensted acids and bases are
no more substances, but individual types of particles. Due to the autoprotolysis of H\(_2\)O molecules
(not "autoionization of water"), the following equilibrium exists:

\[
\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq)
\]

Through this protolysis it is more advantageous to argue rather with H\(_3\)O\(^+\) (aq) ions than with
H\(^+\) (aq) ions. In this theory there are still ampholyte particles which react as acid or as base particles
– depending on the reaction partner: H\(_2\)O molecules, NH\(_3\) molecules, HSO\(_4\)^- ions. Water, ammonia
or sodium hydrogen sulfate cannot be regarded as ampholytes – pure water cannot be one time an
acid and another time a base: with the pH of 7 it is always a neutral substance. The article will
show misconceptions of students and point out the better terminology: reflecting this terminology,
students should develop a better understanding of Chemistry! [African Journal of Chemical
Education—AJCE 6(1), January 2016]
INTRODUCTION
The principle of "giving and taking" is well-known in every-day life – less known is the chemical donor-acceptor principle comprising the transfer of protons in acid-base reactions, of electrons in redox reactions, and of ligands in complex reactions. An atom, ion or molecule may give one or more protons, electrons or ligands, while other different particles receive them simultaneously.

At the end of the 17th century the German scientist Stahl designed the Phlogiston theory for explaining the well-observed combustion processes. He created a special definition of the donor-acceptor principle, transferring “phlogiston” from one substance to another one. Observing the combustion of carbon or metal, he suspected the "escape of phlogiston":

\[
\text{Coal } \rightarrow \text{ ash + phlogiston, metal } \rightarrow \text{ metal ash + phlogiston.}
\]

After further observations of the emanation of zinc and lead out of ores and the mysterious appearance of silvery molten metals during the heating of ore-coal mixtures, Stahl concluded the “transfer of phlogiston” from the burning coal to the ore (“metal ash” – today: metal oxide):

\[
\text{Coal (phlogiston) + ore (metal ash) } \rightarrow \text{ metal}
\]

At that time Stahl didn’t know about gases like oxygen or carbon dioxide being involved in combustion processes – it was the French scientist Lavoisier (with the help of Priestley and Scheele) who proved the existence of oxygen, defined the oxidation theory and described the generation of metals by “transfer of oxygen”: metal oxide + carbon \(\rightarrow\) metal + carbon dioxide.

Even today we use this historical idea to introduce the oxidation theory to our beginners in chemistry before later teaching the concept of redox reactions by electron transfer. But the “escape of invisible fire substances” or parts of the Phlogiston theory are often still in mind of young students: empirical surveys prove that – alternative ideas can be found at any time [1].
To transmit the scientific idea and to realize a conceptual change, today's chemistry class should incorporate a series of experiments to detect the invisible oxygen, and also to demonstrate the escaping colorless gases like carbon dioxide and water vapor [1]. From the experimental results simple equations can be derived, i.e. for the reaction of copper oxide with iron:

\[
\text{copper oxide + iron } \rightarrow \text{ copper + iron oxide}
\]

The oxygen seems to be “transferred” from copper oxide to iron in order to produce copper and iron oxide – but you will find neither O atoms, nor oxide ions or O\(_2\) molecules which are emitted or received. Only the redox reaction in terms of an electron transfer offers an appropriate interpretation: one Fe atom emit two electrons that are transferred simultaneously to a Cu\(^{2+}\) ion: the formation of Cu atoms is explained. The oxide ions are spectator ions which are incorporated into the new ionic lattice:

Fe atom \(\rightarrow\) Fe\(^{2+}\) ion + 2 e\(^-\) \hspace{1cm} \text{(loss of two electrons, oxidation of the Fe atom)}

Cu\(^{2+}\) ion + 2 e\(^-\) \(\rightarrow\) Cu atom \hspace{1cm} \text{(gain of two electrons, reduction of the Cu\(^{2+}\) ion)}

Fe atom + Cu\(^{2+}\) ion \(\rightarrow\) Cu atom + Fe\(^{2+}\) ion \hspace{1cm} \text{(redox reaction and electron transfer)}.

In the following paragraphs both electron transfer in redox reactions and proton transfer in acid-base reactions are explained in more detail. The explanation of complex reactions seems to be unnecessary since they are often lacking in the curricula.

**PROTON TRANSFER**

The Danish scientist Broensted defined that the term acid does not mean the substance, but rather an acid particle – the publication of Broensted from 1928 describes this clearly [2]. Examples of different acid particles are listed in Table 1.
Tab. 1: Examples of acid particles according to Broensted

<table>
<thead>
<tr>
<th>Substances</th>
<th>acid particles</th>
<th>additional</th>
<th>particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric acid(aq)</td>
<td>H₃O⁺(aq) ions</td>
<td>H₂O molecules, Cl⁻ (aq) ions</td>
<td></td>
</tr>
<tr>
<td>Nitric acid(aq)</td>
<td>H₃O⁺(aq) ions</td>
<td>H₂O molecules, NO₃⁻ (aq) ions</td>
<td></td>
</tr>
<tr>
<td>Sulfuric acid(aq)</td>
<td>H₃O⁺(aq) ions</td>
<td>H₂O molecules, SO₄²⁻(aq) ions</td>
<td></td>
</tr>
<tr>
<td>Pure sulfuric acid(l)</td>
<td>H₂SO₄ molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium bisulfate(s)</td>
<td>HSO₄⁻ ions</td>
<td>Na⁺</td>
<td></td>
</tr>
</tbody>
</table>

Talking about alkaline solutions, it is necessary to differentiate between substances and particles. So caustic soda or sodium hydroxide solution are called substances, but bases are defined as particles to absorb protons: OH⁻ ions or NH₃ molecules. In the area of acids, it depends on the connection whether a substance or an acid particle is meant.

Fig.1: Molecular models for two acid-base reactions [3]
However, particles cannot generally be divided into acids and bases – depending on the reaction partner, certain particles can react both, as an acid or as a base: H$_2$O or NH$_3$ molecules, OH$^-$ ions or HSO$_4^-$ ions – they are also called ampholytes. It is useful to indicate appropriate symbols for conjugate acid-base pairs: NH$_4^+$ / NH$_3$ or H$_2$SO$_4$/HSO$_4^-$. It is also beneficial to use molecular models (see Fig. 1) or beaker models (see Fig. 2) or sphere packing for crystals [1].

**Terminology for proton transfer.** In chemistry, it is common among experts to use a certain laboratory jargon to communicate quickly. For example, one speaks of sulfuric acid “which gives two protons” – and of course the H$_2$SO$_4$ molecule of pure sulfuric acid is meant; may be also the H$_3$O$^+$ (aq) ion of diluted sulfuric acid is regarded. The experts understand those statements in the laboratory jargon – the learner however cannot classify this and would ask: “Is 1 g or 1 mL of sulfuric acid gives away two protons”? The expert can alternate between the Macro-level, the
Submicro- and the Symbolic level of Johnstone [4] and knows what is meant – but not the learner. Some well-known expressions of laboratory jargon are listed and re-written with scientific formulations based on the Bronsted theory (see Tab. 2).

The last example of taking the involved molecules and ions shows that the function of a buffer can be explained optimally by mentioning the hydronium ions and hydroxide ions: both ions are converted into water molecules and the pH remains constant. Generally, applying Broensted’s theory, one has to decide which molecule or ion reacts as an acid and which molecule or ion reacts as a base. This trains learners to interpretate chemical reactions on the Submicro Level [4] by using atoms, molecules and ions with molecular models (see Fig. 1) or beaker models (see Fig. 2). Finally they should describe and explain reactions on the Symbolic Level by using formulae and equations – they can then understand that all the chemical symbols are shortenings of molecular or crystal structures they know from the Submicro Level.

**Tab. 2:** Examples of the laboratory jargon concerning acids and bases and scientific terminology by the Bronsted theory (proton = H\(^+\) ion, HAc = HOOCCH\(_3\), Ac\(^-\) = acetate ion)

<table>
<thead>
<tr>
<th>Laboratory jargon (misconceptions)</th>
<th>Appropriate terminology (Broensted)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Acid-base definitions (also historically)</strong></td>
<td>Acid molecules or ions are proton donors. HAc molecules contain H atoms which can be donated as H(^+) ions to H(_2)O molecules to form H(_3)O(^+) ions. By neutralization an HAc molecule or an H(_3)O(^+) ion gives a proton to an OH(^-) ion: HAc + OH(^-)(aq) → H(_2)O + Ac(^-)(aq) H(_3)O(^+)(aq) + OH(^-)(aq) → 2 H(_2)O, Na(^+)(aq) ions remain</td>
</tr>
<tr>
<td>Acids contain hydrogen, by neutralization it can be replaced by a metal: from CH(_3)COOH the composition CH(_3)COONa can be derived (Liebig 1824)</td>
<td>HCl molecules are protolyzing: they are giving protons to H(_2)O molecules, H(_3)O(^+) (aq) ions and Cl(^-)(aq) ions are formed and are the main particles of hydrochloric acid (see Fig. 1),</td>
</tr>
<tr>
<td>Hydrogen chloride dissociates into ions to form hydrochloric acid: HCl → H(^+) + Cl(^-) (Arrhenius 1887)</td>
<td></td>
</tr>
</tbody>
</table>

| | |
Sulfuric acid dissociates into ions:
\[ \text{H}_2\text{SO}_4 \rightarrow 2 \text{H}^+ + \text{SO}_4^{2-} \]
(Arrhenius 1887)

Sodium hydroxide dissociates into ions:
\[ \text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^- \]
(Arrhenius 1887)

The self-dissociation of water incorporates the equilibrium by ions:
\[ \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^- \]

Water is an ampholyte: it can be an acid or a base

The concentration of water is calculated:
\[ c = 55.5 \text{ mol/L} \]

Strong acid means low pH, weak acid means relatively high pH

Acetic acid is a weak acid with low concentration

Neutralization makes HAc and NaOH a conjugated acid-base pair

2. Examples for carbonate-acid reactions

Sodium carbonate reacts with hydrochloric acid:
\[ \text{Na}_2\text{CO}_3(s) + 2 \text{HCl}(aq) \rightarrow 2 \text{NaCl}(aq) + \text{H}_2\text{CO}_3(aq) \]
\[ \text{H}_2\text{CO}_3(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(aq, g) \]

Calcium carbonate reacts with citric acid:
\[ \text{CaCO}_3(s) + 2 \text{HCit}(aq) \rightarrow \text{CaCit}_2(aq) + \text{H}_2\text{CO}_3(aq) \]
\[ \text{H}_2\text{CO}_3(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(aq, g) \]

H\text{O}^+ (aq) ions are the proton donors

In pure sulfuric acid H\text{SO}_4 molecules are the proton donors, in diluted sulfuric acid the H\text{O}^+ (aq) ions are the proton donors (partly HSO\text{4}^- (aq) ions too)

Na\text{+} ions and OH\text{−} ions form in solid sodium hydroxide an ionic lattice. Dissolving in water they are separated by H\text{2}O molecules into hydrated Na\text{+}(aq) ions and OH\text{−}(aq) ions

The autoprotolysis of H\text{2}O molecules provides an equilibrium with ions:
\[ \text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \]

H\text{2}O molecules are ampholytes: the molecule can either give a proton (as an acid) or may take a proton (as a base) – depending on the partner

The concentration of H\text{2}O molecules in water is:
\[ c = 55.5 \text{ mol H}_2\text{O molecules/Liter} \]

Strong acids are completely protolyzed, weak acids are partly protolyzed, an equilibrium between molecules and ions exists:
\[ \text{HAc} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{Ac}^-(aq) \]

The HAc molecule is a weak acid, HAc molecules exist in equilibrium with corresponding ions

Conjugated acid base pairs differ by one proton and are HAc / Ac\text{−} and H\text{2}O / OH\text{−}

Carbonate ions are the proton acceptors:
\[ \text{CO}_3^{2-} + 2 \text{H}_3\text{O}^+(aq) \rightarrow 2 \text{H}_2\text{O} + \text{H}_2\text{CO}_3(aq) \]
\[ \text{H}_2\text{CO}_3(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(aq, g) \]

Na\text{+}(aq) ions and Cl\text{−}(aq) ions don’t participate in the reaction, they remain as “spectator ions”

HCit molecules are the proton donors:
\[ \text{CO}_3^{2-} + 2 \text{HCit}(aq) \rightarrow \text{H}_2\text{CO}_3(aq) + 2 \text{Cit}^-(aq) \]
\[ \text{H}_2\text{CO}_3(aq) \rightarrow \text{H}_2\text{O} + \text{CO}_2(aq, g) \]

Ca\text{2+}(aq) ions are spectator ions
3. Neutralization of acid solutions by sodium hydroxide

Example hydrochloric acid: molecules are reacting, salt and water are being produced:

\[ \text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O} \]

Example acetic acid solution: molecules are reacting, salt and water are being produced:

\[ \text{HAc} + \text{NaOH} \rightarrow \text{NaAc} + \text{H}_2\text{O} \]

4. Acetic acid-acetate buffer

By adding an acid to the buffer solution, sodium acetate reacts:

\[ \text{NaAc} + \text{HCl} \rightarrow \text{NaCl} + \text{HAc} \]

By adding hydroxide, acetic acid reacts:

\[ \text{HAc} + \text{NaOH} \rightarrow \text{NaAc} + \text{H}_2\text{O} \]

\[ \text{H}_3\text{O}^+(\text{aq}) \text{ ions and OH}^-(\text{aq}) \text{ ions react to form H}_2\text{O molecules: H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow 2 \text{H}_2\text{O} \]

\[ \text{Na}^+(\text{aq}) \text{ and Cl}^-\text{(aq) ions don’t participate in the reaction, they remain (see Fig. 2):} \]

\[ \text{In weak acetic acid, two acid particles exist and react with OH}\text{^-(aq) ions:} \]

1. \[ \text{HAc} + \text{OH}^-\text{(aq)} \rightarrow \text{H}_2\text{O} + \text{Ac}^-\text{(aq)} \]
2. \[ \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-\text{(aq)} \rightarrow 2 \text{H}_2\text{O} \]

\[ \text{Na}^+(\text{aq}) \text{ and Ac}^-\text{(aq) ions don’t participate} \]

In buffer solution with pH about 4.7, the HAc molecules and Ac\textsuperscript{−}(aq) ions exist in equal concentrations. By adding hydronium ions, acetate ions react, water molecules are produced:

\[ \text{H}_3\text{O}^+(\text{aq}) + \text{Ac}^-\text{(aq)} \rightarrow \text{H}_2\text{O} + \text{HAc} \]

By adding OH\textsuperscript{−}(aq) ions, HAc molecules react and also water molecules are being produced:

\[ \text{OH}^-\text{(aq)} + \text{HAc} \rightarrow \text{H}_2\text{O} + \text{Ac}^-\text{(aq)} \]

Fig. 3: Mental model according to electron transfer of two electrons [5]
Talking about electron transfer, the same question should be asked: from which atom, ion, or molecule is an electron coming, and to which particle is it being transferred? The example of the magnesium-oxygen reaction clarifies this perfectly (see Fig. 3): the Mg atom emits two electrons and is thus converted into an Mg$^{2+}$ ion, the O₂ molecule is split into O atoms, each O atom absorbs two electrons and is converted into an O$^{2-}$ ion. According to the used definition of “oxidation of magnesium” we also say: the Mg atoms is being oxidized, the O atom is being reduced (see Fig. 3):

\[
\text{Mg atom} \rightarrow \text{Mg}^{2+} \text{ ion} + 2 \text{e-} \quad \text{oxidation} = \text{electron emission from a particle} \\
\text{O atom} + 2 \text{e-} \rightarrow \text{O}^{2-} \text{ ion} \quad \text{reduction} = \text{electron reception of a particle} \\
\]

\[
\text{Mg atom} + \text{O atom} \rightarrow \text{Mg}^{2+} \text{ ion} + \text{O}^{2-} \text{ ion} \quad \text{redox reaction} = \text{electron transfer}
\]
Likewise, for the well-known reaction of an iron nail in copper sulfate solution (see Fig. 4), one has to argue: not “iron” but Fe atoms are being oxidized, and Cu$^{2+}$ (aq) ions are being reduced [7]. The sulfate ions remain completely uninvolved: they are “spectator ions”.

**Terminology for electron transfer.** Concerning redox reactions the common laboratory jargon one states often: “iron gives two electrons” – and a mixture of substances and particles is used. This unconscious mixing confuses the learner and provides unclear facts. Table 3 shows examples of incorrect statements and their corrections. Likewise reaction equations, in which only “numbers of atoms on the left and on the right hand side of the arrow” are compensated, are part of the laboratory jargon: they don’t serve to explain redox reactions in an understandable way (see Tab. 2 with respect to acid-base reactions). For clarity, we select the symbol H$^+$ (aq) for redox reactions – and not, as previously, the symbol H$_3$O$^+$ (aq): for the explanation of the proton transfer, this symbol is easier to understand.

**Tab. 3:** Examples of the laboratory jargon for redox reactions and appropriate terminology

<table>
<thead>
<tr>
<th>Laboratory jargon (misconceptions)</th>
<th>Appropriate terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Redox definitions (also historically)</strong></td>
<td>Mg atoms are being oxidized, O atoms are reduced:</td>
</tr>
<tr>
<td>Magnesium is being oxidized taking oxygen: 2 Mg (s) + O$_2$ (g) $\rightarrow$ 2 MgO (s) (Lavoisier 1784)</td>
<td>2 Mg atoms $\rightarrow$ 2 Mg$^{2+}$ ions + 4 e- O$_2$ molecule + 4 e- $\rightarrow$ 2 O$^{2-}$ ions (see Fig. 3)</td>
</tr>
<tr>
<td>Copper oxide reacts with magnesium: copper oxide is being reduced, gives off oxygen, magnesium oxidizes and takes oxygen: CuO (s) + Mg (s) $\rightarrow$ Cu (s) + MgO (s) (Lavoisier 1784)</td>
<td>Mg atoms are being oxidized, Cu$^{2+}$ ions are reduced: Mg atom $\rightarrow$ Mg$^{2+}$ ion + 2 e- Cu$^{2+}$ ion + 2 e- $\rightarrow$ Cu atom O$^{2-}$ ions merely change the ionic lattice</td>
</tr>
</tbody>
</table>
2. **Metal-acid reactions**

Magnesium reacts with hydrochloric acid, gaseous hydrogen escapes:
\[ \text{Mg(s)} + 2 \text{HCl(aq)} \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g}) \]

Magnesium reacts with diluted sulfuric acid, magnesium is being oxidized:
\[ \text{Mg(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{MgSO}_4(\text{aq}) + \text{H}_2(\text{g}) \]

Magnesium reacts with pure sulfuric acid, gaseous hydrogen sulfide escapes:
\[ 4 \text{Mg(s)} + 5 \text{H}_2\text{SO}_4(\text{l}) \rightarrow \text{H}_2\text{S}(\text{g}) + 4 \text{MgSO}_4(\text{s}) + 4 \text{H}_2\text{O} \]

3. **Reactions of metals with salt solutions**

Iron reacts with copper chloride solution, iron is being oxidized, copper chloride reduced:
\[ \text{Fe(s)} + \text{CuCl}_2(\text{aq}) \rightarrow \text{Cu(s)} + \text{FeCl}_2(\text{aq}) \]

Copper reacts with silver nitrate solution, copper is being oxidized, silver nitrate reduced:
\[ \text{Cu(s)} + 2 \text{AgNO}_3(\text{aq}) \rightarrow 2 \text{Ag(s)} + \text{Cu(NO}_3)_2(\text{aq}) \]

4. **Permanganate-hydrochloric acid reaction**

In this reaction gaseous chlorine is formed from hydrochloric acid:
\[ \text{KMnO}_4(\text{s}) + 4 \text{HCl(\text{aq})} \rightarrow 1.5 \text{Cl}_2(\text{g}) + \text{MnO}_2(\text{s}) + \text{KCl(\text{aq})} + 2 \text{H}_2\text{O} \]

5. **Oxygen corrosion**

Iron corrodes in moist air forming iron hydroxide,
iron is thereby being oxidized:
\[ 2 \text{Fe(s)} + 2 \text{H}_2\text{O} + \text{O}_2(\text{aq}) \rightarrow 2 \text{Fe(OH)}_2(\text{s}) \]
6. Daniell cell

Zinc and copper are dipped in their 1-molar solutions, the voltage of $U = 1.1 \text{ V}$ occurs:

$$
\text{Zn(s)} + \text{CuSO}_4(\text{aq}) \rightarrow \text{Cu(s)} + \text{ZnSO}_4(\text{aq})
$$

The equilibria shift to the right, when Zn atoms are being oxidized and Cu$^{2+}$ ions reduced:

$$
\text{Zn atom} \quad \leftrightarrow \quad \text{Zn}^{2+} \text{ ion} + 2 \text{ e-}
$$

$$
\text{Cu}^{2+} \text{ ion} + 2 \text{ e-} \quad \leftrightarrow \quad \text{Cu atom}
$$

Fig. 5: Mental model of proton transfer between electron clouds [9]

ALTERNATIVE MENTAL MODELS OF DONOR-ACCEPTOR REACTIONS

The figures 1-4 suggest independently co-existing protons and electrons that move from one particle to another. This mental model should be preliminary for the learners in Piaget’s development stage of concrete operations. In further lessons this concept can be extended by describing atoms, ions and molecules with electron clouds. Using the example of reacting HCl and H$_2$O molecules, a mental model is proposed with the transfer of protons from one electron cloud to the other (see Fig. 5). Christen and Baars [9] state: "There are no free, self-existing H$^+$ ions (as it was postulated in 1883 by Arrhenius); the proton which is initially bound to the chlorine atom by a pair of electrons, separates from these electrons, shifts then in one of the two electron clouds of the oxygen atom, and is finally bound by these electrons" [9].
Due to the wave-particle duality, electrons can be regarded as particles, but they should be also seen as standing waves or elementary electric charges. These charges are discharged from the electron clouds of atoms, ions or molecules and absorbed by electron clouds of other particles. The electron clouds can be measured today by electron density – they are never punctate structures.

In many cases, electrical charges are not being transferred, but only postponed: "The redox process often consists of an electron shift" [9]. For example, hydrogen and oxygen react to form water, the reaction is called a redox reaction: \[2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}\]. According to the oxidation states, an electron transfer can be presumed, but actually the electron pairs or electron clouds of the O atoms are merely shifted: from non-polar covalent bonds in the \text{O}_2 molecule to strongly polar covalent bonds in the \text{H}_2\text{O} molecule: the result is an electron shift, not an electron transfer. But learners in the development stage of concrete operations may perceive protons and electrons as tiny particles and describe still proton or electron transfers. Later in advanced classes it is up to the teacher to switch to explanations on the abstract level of electron clouds or wave-particle duality.

CONCLUSIONS

Learners in chemistry classes should firstly work on the Macro Level of substances and reactions [4], without using models and chemical symbols: many experiments and chemical reactions can be observed and described with reaction symbols in words. Once the Submicro Level of smallest particles starts, the learner should consistently argue with smallest particles: the level of substances and the level of particles should not be arbitrarily mixed [4]. In particular, with the introduction of atoms and molecules, it would be desirable, to introduce also the ions – even without differentiated atomic models [10]. Thus, the structure of salt crystals and of salt solutions can be described scientifically correct with ions – without provoking misconceptions [1]. In particular, a "structure-based chemistry education" would be advantageous with the use of simple
models such as sphere packing, space lattices, molecular models and beaker models [10]: they lead to appropriate mental models of the structure of matter and to the model of regrouping atoms, ions and molecules in chemical reactions on the Submicro Level [4]. And finally, they are the prerequisite for the successful introduction and use of formulae and equations on the Symbolic Level [4]: formulae should never be abbreviations – they should be shortened models of the structure of matter!

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DEVELOPING AND IMPLEMENTING ASSESSMENT MODERATION PROCEDURES TO EVALUATE WRITTEN LABORATORY REPORTS

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ABSTRACT
In evaluating laboratory reports, assessment criteria must be clearly established and made explicit to students before the lab activities so students can focus their efforts and the instructors will concentrate on major learning outcomes during marking the laboratory reports. This paper is intended to help draw assessment moderation procedures to significantly minimize discrepancies between teachers in marking lab reports. It also helps students to develop their report writing skills. A population of 193 students taking two chemistry laboratory courses and a team of three instructors were used as research group. The students were required to respond on the extent of instructors’ subjectivity during marking lab reports, and on its impact on their motivation and learning. Marks given by the instructors to lab reports were compared and evaluated for significant differences. Based on the responses of the students and marks issued by the instructors, a moderation procedure was proposed, implemented and evaluated for its effectiveness in improving students’ motivation and learning. The research showed that there is a clear observation and evidence of lack of skills on students’ side about report writing before moderation. It also indicated that teachers assessed the reports on subjective basis rather than objectively designed marking criteria. The implementation of the moderation procedure helped reducing the instructors’ discrepancies in marking lab reports and brought significant improvements on students’ motivation and achievements. [African Journal of Chemical Education—AJCE 6(1), January 2016]
INTRODUCTION

Written laboratory reports are among the different types of assessment tasks. A laboratory report is a common way of presenting information and recommendations or conclusions related to a specific purpose. The reports are presented based on gathering and analyzing information using a discipline specific methodology and format. They can also be used to assess field work or case studies. Carefully designed assessment tasks allow students to demonstrate achievement of clearly communicated learning outcomes. The assessment designs should include the following three elements: the learning outcomes must be clear, the learning experiences should help students achieve those learning outcomes, and the assessment tasks must allow students to demonstrate their achievement of the learning outcomes [1].

The laboratory report mark is one obstacle that tends to create conflicts between teachers and students, between students and between teachers. Some way of marking, grading and evaluating pupils’ work is necessary. In spite of the long persisting criticisms of laboratory marks for unreliability as well as adverse emotional effects upon learners and teachers, the practical reality of certain contributions of effective assessment procedures in promoting individual learner’s own realistic conception of himself/herself is recognized [2]. It is also argued that evaluation is rarely free from personal and other sources of bias. To some extent, these biases are reduced where assessment is shown to be credible, dependable, and confirmable [3].

Moderation, a quality assurance process directed at ensuring that assessments are marked with accuracy, consistency and fairness, is required for every assessment which involves a degree of subjectivity. It is aimed at ensuring that marks and grades are as valid, reliable, equivalent and fair as possible for all students and all markers [4]. Also, it is the most effective criteria used to minimize significant differences in assessing students’ works particularly when many teachers
instruct and assess the same course for different classes. Moderation helps to ensure that there is an appropriate focus on outcomes for learners, that learning is at the appropriate level and that learners develop the skills for learning, skills for life and skills for work, including higher order thinking skills, which will allow them to be successful in the future. Teachers involved in developing their assessment approaches through participation in moderation activities acquire a highly effective form of professional development. Efficient and effective approaches to quality assurance and moderation will require building on local practices, developing working approaches across education authorities and partners and linking this work at a national level. [5]

Moderation includes the entire assessment event, including the design and post-event analysis of the fitness of the assessment of student learning. During moderation, assessments are designed so that they are clearly linked to the intended learning outcomes; pre-marking meetings or other activities are undertaken to ensure that assessors are able to clarify their understanding of the assessment criteria; assessment criteria are clearly communicated to students, both in the pre-assessment phase and also when providing feedback; and assessments are subject to regular review: their frequency, style and the relative success rate of students are appraised as a regular part of the improvement cycle. Effective assessment moderation activities are achieved by using marking criteria, discussions of standards, cross marking and avoiding post-hoc adjustment of marks in higher education. The first phase of moderation is to review all lab report items collaboratively with all markers before the assessment is set and make amendments as required. The second phase of moderation is the implementation, marking and grading that is done before marks are allocated. If there are multiple markers, conduct a consensus marking exercise such as double or triple marking a sample of anonymous items and compare marks, comparing marking
ranges across different groups and markers and giving timely and sensitive feedback to learners and markers [6].

Marks and grades given to students are commonly made by subject specific decision making processes as judgments about academic standards [7]. Ensuring consistency of assessments in a unit is a challenge when a unit is offered on more than one campus and by more than one marker [8]. Marking and grading in most disciplines is inevitably subjective [9] but a systematic approach to identifying significant tacit beliefs may assist in reducing the effect on variation [10]. Conversations amongst markers assessing student performances influenced how the group of markers reached agreement [11]. Despite the potential benefits of team work, moderation of marking is essential for students to feel confident that they will be rewarded fairly for their contributions and that any ‘free-riders’ will not benefit from the efforts of others.

PURPOSE, RESEARCH QUESTIONS AND METHODOLOGY

The aim of the research is to find out the level of teachers’ subjectivity in marking laboratory reports and its impact on students’ learning. It also tries to assess some moderation activities that promote students’ laboratory report writing skills and their motivation to learn through practice by reducing teachers’ subjectivity in marking laboratory reports in chemistry laboratory sessions.

The research is intended to give answers for the following questions:

1. What is the students’ perception of teachers’ discrepancy in marking lab reports and its impact on learning?

2. What is the level of discrepancies between teachers, and within themselves, during marking lab reports?
3. Do the proposed assessment moderation procedures help minimizing the inconsistency between teachers in marking lab reports?

4. What is the effect of assessment through moderation on students’ learning and motivation?

The research was carried out in Debre Markos University, Ethiopia. It is an evaluative type study consisting of a population of 193 students who completed two consecutive laboratory courses, and a team of three instructors. Four 5-scale Likert style questionnaires were prepared to be filled by students. In the questionnaires, strongly agree (SA) had 5 points, agree (A) 4 points, neutral (N) 3 points, disagree (D) 2 points and strongly disagree (SD) 1 point. Questionnaire 1 assessed the students’ perception of the discrepancies between instructors in marking lab reports. Questionnaire 2 asked students responses on the effect of the discrepancy on their motivation and achievement. Questionnaire 3 consisted of ten items. It was aimed at evaluating the students’ attitudes towards the proposed assessment moderation procedure. The reliability and validity of the items in the instrument were evaluated by calculating the Cronbach’s alpha coefficient. Questionnaire 4 emphasizes the effect of the proposed moderation on students’ achievement.

In addition, triplicate copies of 6 lab reports of three groups of students were each marked by the three instructors before and after implementation of the procedure. The results were recorded and evaluated for significant discrepancies between the instructors’ markings using a paired student’s $t$-test statistics.

**RESULTS AND DISCUSSIONS**

In this section, data are presented based on which answers to research questions are discussed. The results are presented and discussed below.
1. Students' perception of discrepancies between teachers in marking lab reports and its impact on their learning

As shown in table 1 below, 153 out of 193 students (79.27%) have agreed that there is significant subjectivity from instructors in marking lab reports and 8 (4.15%) students argued that there is no subjectivity from instructors in assessing students’ lab reports. 32 (16.58%) of the students responded that they have no idea regarding teachers subjectivity in assessing reports. The results in table 2 indicated that of the 153 students who claimed the presence of instructors’ subjectivity, 80 students (52.28%) responded that their motivation and achievement has been affected; 41 (26.80%) have no comment and 32 (20.92%) said their motivation and achievement is not affected by subjective assessment methods during marking lab reports.

Table 1: Students’ perception of teachers’ subjectivity in marking lab reports before moderation: Is there discrepancy, among teachers, during marking lab reports?

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>Average</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>39</td>
<td>114</td>
<td>32</td>
<td>8</td>
<td>-</td>
<td>3.95</td>
<td>0.5343</td>
</tr>
</tbody>
</table>

Table 2: Students responses on effects of discrepancy on their motivation and learning
If your response for subjectivity is SA or A, does it affect your motivation and achievement?

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>Average</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22</td>
<td>58</td>
<td>41</td>
<td>20</td>
<td>12</td>
<td>3.38</td>
<td>1.12</td>
</tr>
</tbody>
</table>

2. Students’ responses on the proposed assessment moderation strategies

After evaluating the reliability and validity of the pilot questionnaire using Cronbach’s alpha, a six item questionnaire was administered and distributed for students to respond. As shown in table 3 below, 131 out of 153 (85.61%) the students demand the instructors to provide clear instructions and all necessary information before submission of the lab reports. 9.16% have no opinion, and 5.23% showed disagreement about the idea of clear instructions and essential information for lab report writing.
Another proposed item that receives good attention was marking all students’ reports of the same experiment by the same instructor. 75.16% of the respondents claim their agreement, 10.56% have no idea, and 14.38% did not support the idea. Even though a smaller number of instructors are advisable to assess the same subset of lab reports, research has shown that same instructor marking is not applicable for a large number of students-to-faculty ratio case [12].

The other well rated proposed procedure by the students was provision of specific lab report formats. 69.9% remarked they needed specifically designed lab report formats, 11.11% were neutral and 19.61% responded negatively. Availability of specific lab report formats helps students to be specific and concentrate on major issues of the report. It also makes the teachers at ease in comparing students work as they focus on similar parts of the report. Laboratory reports should always be written for the convenience of the reader. Thus, for example, each section of the report should be headlined and the sections should be arranged in an appropriate, easily-understood sequence. In the context of the course for which it is written, the laboratory report serves to describe what the students did during the laboratory session, how they manipulated the raw data, what they identified as their result and what they concluded about the experiment [13].

Instructors’ timely and meaningful feedback was the other proposed activity in moderation of lab report assessments. The idea of getting on time and meaningful feedbacks about their lab reports was supported positively by almost 68% of the students. 5.23% of the respondents have no comments and about 25.5% have opposed the procedure. Timely and meaningful feedback is essential to learning and to sound assessment practice. Balancing learning goal and efficiency is a key aspect of effective feedback. The most useful forms of feedback are those which help students learn most effectively and help teachers work most efficiently [14].
Another proposed procedure to reduce inconsistency between instructors during marking lab reports was to use marking guides (criteria). More than 63% of the students suggested that instructors should prepare and use marking guides during assessment of lab reports. Some 24.34% were neutral and the rest 12.5% did not support it. Marking guides make explicit to the students the criteria against which their work will be assessed and they can be a comprehensive and efficient feedback tool. A marking guide is advantageous in that it makes assessment processes open and accountable, provides diagnostic feedback to students and staff on students’ learning so far, helps students develop, revise and produce better quality work as they do not have to guess what the assessor is looking for because the most valued outcomes of the assessment are clear. It improves comparability when there are several assessors and can be re-used [15]

Table 3: Students’ responses on proposed procedures to minimize teachers’ discrepancies in marking lab reports

<table>
<thead>
<tr>
<th>No</th>
<th>Proposed procedures</th>
<th>Students’ responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SA</td>
</tr>
<tr>
<td>1</td>
<td>clear instructions and all information initially</td>
<td>59</td>
</tr>
<tr>
<td>2</td>
<td>reports of the same experiment should be marked by the same instructor</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>provide lab report marking guide</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>give specific formats for lab report writing</td>
<td>42</td>
</tr>
<tr>
<td>5</td>
<td>give on time and meaningful feed-backs</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>give pre-lab and post-lab exercises</td>
<td>41</td>
</tr>
</tbody>
</table>

Sd* = standard deviation

Furthermore, 58.8% showed their interest in handing of pre and post lab exercises along with the formal lab procedures. 11.76% remain neutral and 21.57% assert that no pre and post lab exercises are required. For many experiments, students are required to have a complete, written pre lab activity before they are allowed to work on the experiment. In order to truly understand lab and to be able to draw appropriate conclusions, a learner must first carefully consider the how, what and why of a lab practice. Research has shown that students who have a written preparation
for lab are safer, more efficient and have a better understanding of how the lab connects to theory [16].

3. Students’ responses on effects of assessment through moderation on their achievement

Depending on results of students’ opinions on strategies to minimize discrepancies in marking lab reports, a moderation procedure to assess students’ laboratory reports was proposed and implemented. The procedure consisted of providing clear instruction about report writing, specific formats, pre-lab activities and exercises, well designed marking guide (rubric) and immediate and meaningful feedback. The instructions, lab report formats and marking guide are shown in appendices 1 and 2.

The data in table 4 showed 122 students out of 146 (83.56%) have agreed that the proposed assessment moderation helped them improve their report writing skills and achieve better results.

Table 4: Students’ responses to the effects of moderation on their learning
Did the instructions, lab report formats, pre-lab activities, feedbacks and marking guides (moderation procedures) provided by the instructors help you improve your skills in writing lab reports and achieve better results? Indicate your marks (out of 60%).

<table>
<thead>
<tr>
<th>Answer</th>
<th>Number of students Responding</th>
<th>Marks out of 60 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, very well</td>
<td>32</td>
<td>30-40 41-50 51-60</td>
</tr>
<tr>
<td>Yes, to some extent</td>
<td>77</td>
<td>- 51 26</td>
</tr>
<tr>
<td>No, I achieve better by my own effort</td>
<td>13</td>
<td>2 4 7</td>
</tr>
<tr>
<td>No, it doesn’t help me</td>
<td>10</td>
<td>2 5 3</td>
</tr>
<tr>
<td>No, the instructors become more strict</td>
<td>14</td>
<td>1 8 5</td>
</tr>
</tbody>
</table>

Thirty two students (21.9%) remarked it helped them very well, 77 students (52.7%) responded the moderation made them improve to some extent, 13 students (8.90%) have shown improvement but they argue it came from their own effort. 24 students (16.44%) responded negatively. 14 (9.59%) claimed the procedure made instructors more strict during marking the reports. Students’ results shown in table 5 also indicated that they have made significant improvements after the implementation of the assessment through moderation. The students’
responses on the effects of the moderation activities on their achievement match with findings of research [12, 15].

Table 5: Average marks (out of 10%) issued by different instructors before (1) and after (2) moderation procedures

<table>
<thead>
<tr>
<th>Experiment No</th>
<th>Before/after moderation</th>
<th>Mark given by three Instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>7.83 ± 0.29*</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.33 ± 0.29</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>7.33 ± 0.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.83 ± 0.86</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.67 ± 0.29</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>7.5 ± 0.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8 ± 0.5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>7.83 ± 0.64</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8 ± 0.5</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>8 ± 0.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>9 ± 0.5</td>
</tr>
<tr>
<td>Average</td>
<td>1</td>
<td>7.75 ± 0.51</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.42 ± 0.37</td>
</tr>
</tbody>
</table>

* Standard deviation

4. Comparison of discrepancies between and within instructors in marking lab reports before and after moderation

When assessing multidisciplinary lab reports, instructors with different backgrounds can focus on different aspects of the report and they can use different marking criteria. These discrepancies have traditionally been analyzed by calculating and comparing the mean and variance of the marks of each instructor. In a lab course with a high student-to-teacher ratio, the number of lab reports to assess is too large for the available advising hours, so the usual procedure adopted is to have a large number of instructors involved in the course. However, the larger the number of instructors, the higher the risk of marking discrepancies is [12].

Differences between the mean values of the various marks students received in this study were evaluated by student’s paired t-test. In pair-wise student’s t-test, the experimental t-statistic value is calculated using the equation:
Where \( A = \frac{n_1 + n_2}{n_1 \cdot n_2} \) and \( B = (n_1 - 1)S_1^2 + (n_2 - 1)S_2^2 \)

The number of degrees of freedom for finding the \( t \) values is \( (n_1 + n_2) - 2 \), where \( n_1 \) and \( n_2 \) are number of replicate copies of lab reports marked by instructor 1 and 2 respectively, and \( s_1 \) and \( s_2 \) are the corresponding standard deviations. If \( t_{exp} \) is smaller than the tabulated \( t \) value at 95% confidence level, no significant discrepancies between the two means has been observed. On the other hand, if \( t_{exp} \) is greater than the value obtained from table indicates that there is a significance difference between the means.

The data of table 6 indicated the prevalence of significant discrepancies between instructors during marking lab reports. Instructors A and B made significant differences in three of six lab reports before the moderation procedures as compared to only one significant difference after moderation. Also, three significant differences were observed between instructors A & C, and B & C each before moderation. No significant discrepancies were seen between A & C after moderation while one significant difference occurs between B & C. Concerning the overall averages, significant differences were made between A & C and B & C before moderation but no differences are made after implementation of moderation.

The results in table 7 also indicated that there were discrepancies within instructors themselves before and after implementation of the assessment procedure in marking lab reports. There was only on significant difference within the marks given by instructor A while four significant differences were observed (out of six) within the marks delivered by each of instructors B and C. The statistical data showed the proposed procedure helped reducing the discrepancies made between a number of teachers providing the same course for different groups and classes of
students. This fact is especially relevant when the marking workload is large and does not allow each lab report to be assessed by few instructors.

Table 6: Pair-wise comparison between mean values of marks issued by different instructors using statistical student’s t values at the 95% confidence level before (1) and after (2) moderation (student’s t-statistics at 95% CL for 4 degrees of freedom is 2.78)

<table>
<thead>
<tr>
<th>Averages compared</th>
<th>Before/after moderation</th>
<th>Experiment No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1  2  3  4  5  6</td>
</tr>
<tr>
<td>A vs. B</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>A vs. C</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>B vs. C</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

*significant differences exist between the mean marks

Table 7: Pair-wise comparison between mean values of marks issued by the same instructor before and after implementation of moderation using statistical student’s t values at the 95% confidence level (student’s t-statistics at 95% CL for 4 degrees of freedom is 2.78)

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Experiment No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

*significant differences exist within the mean marks

CONCLUSIONS

The researcher who was involved in the preparation and implementation of the moderation procedure reported the following conclusions and recommendations.

- One of the keys to success (or failure) of moderation of assessments in written subjective assessments seems to be related to the manner in which they were implemented and how well the students were instructed about how to use the procedures. The instructors reported they believed that 1st year students require more guidance and instruction about report writing.
• Another key to the success of the rubric is the experience that the students have with the material. For students with little experience with an assignment such as lab reports, material such as sample reports or checklists are needed to supplement the formats and marking guides as a tool for students to understand what is expected with an assignment.

• Lab reports marked with a marking guide typically had a larger spread in marks than assignments corrected without a marking guide. This appeared to be caused by the instructor being forced to apply a predetermined standard with a marking guide. It was easier as a marker to give a high or low mark on an element of an assignment when it was clear what the standard was. One result of the marking was that the students had set standards to work toward which resulted in better reports by the end of the semester than semesters without formats and guides.

• Instructors collaboration during the development and implementation of assessment through moderation appear to be important to the standardization of the marking. In the case of a lab course, the team of instructors discussed the rubrics including the rationale behind the objectives and criteria. These efforts seemed to be important in the relative success of using moderation to standardize the marking. In the absence of assessment through moderation, the students had many complaints about non-consistent marking with different instructors.

• The students appeared to pay more attention to the criteria when they were given the formats and marking guides well in advance of the report writing and asked to use them to evaluate their own work prior to handing in the lab reports.

• Once students become comfortable with instructions, lab report formats and marking guides, they can provide valuable feedback in the moderation refinement process. The
students in each of the lab experiments provided ample feedback and opinions, some of which were very useful to the refinement process. For example, it became especially clear, that the first year students needed extra support and detail in the moderation.

- Comprehensive and well-written instructions, lab formats and marking guides can help the students understand the professional standards under which their future work as practicing chemists will be evaluated.

REFERENCES

2. Charles E.Skinner, *Educational Psychology*, Macmillan publishers, New Delhi, 2005
13. Connors Writing Center, *Lab reports*, Dimond Library 329, UNH. writing.center@unh.edu 603-862-3272


**Appendix 1: Instructions and lab report formats**

| Title | Specific, clearly conveys purpose of lab, can be abbreviated on subsequent pages. |
| Date | On first page, original date of starting lab activities |
| Lab Partners | Clearly listed on first page of lab report |
| Purpose | One sentence or two explaining the purpose of the experiment or the problem being investigated. Be specific but concise, this should relate directly to the conclusion you will draw, you may want to add to or change your purpose after completing the lab. |
| Materials | Complete list in columns or bullets |
| Procedure | Written as a list of numbered steps. Steps taken are specific enough so that someone not familiar with the lab or your work could do the procedure and repeat your results. Changes to procedure within a trial can be documented in observations, and you may need to include safety procedures if any. |
| Data Tables | Make table(s) large enough to write in, You may have to create your own table(s) if one is not given on your manual before coming to class. |

**Title:** Placed at the top of the first page, this should include the title of the experiment, the name(s) of the person(s) performing the experiment, and the date it was performed.

**Objective:** This is a statement of the purpose of the lab. What are the main reasons you are performing this experiment? Be specific...don't just restate the title or copy the generic objectives from the given lab manual.

**Equipment:** A bulleted list of all the equipment and chemicals you will use in this experiment

**Procedure:** A numbered sequence of steps you followed as you perform the experiment. Try to be brief, but include enough detail in passive voice so others can follow this in the lab.

**Data / Observations:** This is where you record all the measurements and observations you made during the lab, and attach any tables, graphs and charts generated during or after the lab to display your data. All data should be organized into labeled data tables with correct significant figures and labeled units. Graphs and charts must include titles, axes labels and units where applicable.

**Calculations:** You must show at least *one* sample calculation for each piece of data in your table that was not simply a measured value. For example, if you record the number of moles of NaCl, but you obtained that from measuring the mass of NaCl, you must show in the calculations section how you got the number of moles from the mass. If you did this step in five different trials, only one sample calculation is sufficient.

**Data Analysis:** This is the main part of the lab report where you *present* the data you collected, *discuss* how you obtained the data (explain calculations, but don’t restate procedure) and *analyze* why the data is relevant. This section of the lab should contain only statements you can support with your data, NOT your opinions. Every statement should be backed up by quoting your data and/or referencing by title, relevant tables, charts or graphs within your report. For example, in your “data” section you recorded the freezing point of unknown sample #1 to be -5 °C. In the “data analysis” section you will further analyze that data: “We used an electronic temperature probe and determined the freezing point of sample #1 to be -5 °C as noted in Figure 2 by the flat portion of the curve. This shows that the addition of a solute (NaCl) lowered the freezing point by 5 °C when
compared to the curve of the pure sample shown in Figure 1." This will undoubtedly be the longest and most difficult section to write up in every lab report.

**Conclusion:** This is a brief paragraph where you: restate your objective, quote data that proves you met or did not meet the objective, describe possible sources of error and how they affected your data and suggest how to improve your results if you were to repeat the experiment.

### Appendix 2: A marking guide to a lab report

<table>
<thead>
<tr>
<th>Heading</th>
<th>Criteria</th>
<th>Performance level</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aim/objective</td>
<td>Purpose of the experiment stated in one’s own words using clear, simple sentences</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very good</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>Conceptuality, relevance to topic significance, language usage, clarity citation available</td>
<td>Good</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very good</td>
<td>1</td>
</tr>
<tr>
<td>Methods/Procedures</td>
<td>Detailed steps written in passive voice</td>
<td>Fair</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Methods of data analysis included</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Relationships between dependent and independent variables indicated</td>
<td>Very good</td>
<td>2</td>
</tr>
<tr>
<td>Results</td>
<td>Data collected in table formats</td>
<td>Fair</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Graphs are available</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Graphs and tables are labeled well</td>
<td>Very good</td>
<td>2</td>
</tr>
<tr>
<td>Discussion</td>
<td>Chemical equations, if any</td>
<td>Fair</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Calculations done properly</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Discussion if the results agree with theory or hypothesis</td>
<td>Very good</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Any possible sources of errors discussed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Any attempt to reduce error indicated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall all Lab report structure</td>
<td>Cover page style</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Neatness and readability</td>
<td>Very good</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Tables and graphs have title</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>Pages are numbered</td>
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</tr>
<tr>
<td>Total points</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
ABSTRACT

The aim of this research was to use different assessment methods by engaging all students in pre-laboratory flow charts with check lists by taking into account rather than giving a mark for attendance for their presence, based on principles of cooperative learning method by forming groups, promoting positive interdependence among individuals, providing individual accountability and helping students to develop teamwork skills and lastly the post laboratory reports evaluation and presentation on selected criteria’s summarizes the research base that attest to the effectiveness of methods and improvement of cooperative learning in practical organic chemistry I class. [African Journal of Chemical Education—AJCE 6(1), January 2016]
INTRODUCTION

Many students who have worked in a team in a laboratory- or project-based course do not have fond memories of the experience. Some recall one or two team members doing all the work and the others simply going along for the ride but getting the same grade. Others remember dominant students, whose intense desire for a good grade led them to stifle their team mates’ efforts to contribute. Still others recall arrangements in which the work was divided up and the completed parts were stapled together and turned in, with each team member knowing little or nothing about what any of the others did. Whatever else these students learned from their team experiences, they learned to avoid team projects whenever possible [1].

Laboratory work is an established part of courses in chemistry in higher education. The original reasons for its development lay in the need to produce skilled technicians for industry and highly competent workers for research laboratories and others [2, 3]. Today, the aims may be different, in that many chemistry first degree graduates are not employed as bench chemists in industry and the needs of research have inevitably become much more specialized as chemical knowledge has expanded [4].

Students typically arrive at the laboratory to carry out an experiment without a very clear idea of the practical techniques they will be using, the skills they will need, or the chemistry which underlies the practical. It is usually only after the laboratory, during a write up, that students will generally start to work out what it was they had been doing all day. This is obviously an unsatisfactory experience and students will clearly get much more from their laboratory work if they know what they are doing beforehand. Pre-laboratory preparation is the key to achieving this and the laboratory skills philosophy has therefore been to shift the balance of work outside the laboratory to before rather than after the practical class so that students are much better informed and more confident. As part of their pre-laboratory work, students are required to work through
some background information about the experiment including sets of multiple choice and multiple completion tests which also provide instant feedback on any wrong answers.

Very frequently, it is asserted that chemistry is a practical subject and this is assumed, to offer adequate justification for the presence of laboratory work. Thus, the development of experimental skills among the students is often a suggested justification. Nonetheless, this argument needs to be questioned to justify the position or role of the laboratory in the field of chemistry education [5].

Cooperative learning is an approach to group work that minimizes the occurrence of those unpleasant situations and maximizes the learning and satisfaction that result from working on a high-performance team. A large and rapidly growing body of research confirms the effectiveness of cooperative learning in higher education [6]. Relative to students taught traditionally, i.e. with instructor-centered lectures, individual assignments, and competitive grading cooperatively taught students tend to exhibit higher academic achievement, greater persistence through graduation, better high-level reasoning and critical thinking skills, deeper understanding of learned material, greater time on task and less disruptive behavior in class, lower levels of anxiety and stress, greater intrinsic motivation to learn and achieve, greater ability to view situations from others’ perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem. Another nontrivial benefit for instructors is that when assignments are done cooperatively, the number of papers to grade decreases by a factor of three or four [7]. The proven benefits of cooperative learning notwithstanding, instructors who attempt it frequently encounter resistance and sometimes open hostility from the students. Bright students complain about being held back by their slower teammates; weak or unassertive students complain about being discounted or ignored in group sessions; and resentments build when some team
members fail to pull their weight. Knowledgeable and patient instructors find ways to deal with these problems, but others become discouraged and revert to the traditional teacher-centered instructional paradigm, which is a loss both for them and for their students [8].

The pre-laboratory instructions have been employed for physics students and cooperative learning styles and laboratory reports also applied on different disciplines. Therefore, this paper describes pre-laboratory flow charts instructions, cooperative learning methods that have been proven effective in a variety of instructional settings and post laboratory report writing with presentation. We then suggested ways to maximize the benefits of the approach and to deal with the difficulties that may arise when pre-laboratory flow charts are drawn for students to have awareness on the experiments, cooperative learning methods to build a team work spirit of students and managing ability on practical organic chemistry I with report writing for to develop the scientific writing skills for their further carrier.

METHODOLOGY
Population was selected from Haramaya University, Chemistry Department year one practical organic chemistry I class students. The study survey designed to use different assessment techniques in practical organic chemistry I laboratory class based on year one chemistry 2012 batch. The design is intend to assess the usefulness of pre-laboratory flow charts and engaging all students in laboratory work, effectiveness of group formation based on cooperative learning elements. In addition to this research designed for the evaluation of post-laboratory report writing and presentation of the selected experiments as well as changing the attitude of fresh students for their further carrier in creating self-confident professionals of chemistry.
Sampling Techniques

In this study all students of year one practical organic chemistry I class students were participated on this experiment and their group organization were taken randomly.

Data Collection Instruments

The students were used pre-laboratory flow charts, laboratory reports with presentation on the selected experiments and post survey as the main instruments for collecting data. In order to gather information and facts through this instrument, check lists, criteria for report writing and presentation were prepared. Post survey questions were developed and distributed to all year one practical organic chemistry I class students.

Method of Data Analysis

In this study, qualitative data collection techniques were used as primary research methods. However, in order to organize, classify and analyze the gathered information, the researchers used mean, average and percentage statistics as a way to measure the students’ level of improvement practical skills through the use of flow chart check lists, criteria for report writing and presentation as well as questionnaire strategies. The main sources of information were the daily observation laboratory assistances and students during the practical organic chemistry I class. The “face to face” interactions gave us the opportunity to deepen into their experiences, thoughts and feelings.
RESULTS AND DISCUSSION

Action Plan, Implementation and Action Evaluation

A. Action Plan

Most of the students were not come up with pre-laboratory activities which make them aware of what will be the experiment rather they say that, “Mr. X will come up with pre lab works like flow charts and home activities before laboratory and perform the tasks as usual”. And not engagement of all group members to perform the laboratory activities rather two or three (2 or 3) individuals do the activity.

In addition, when students self-selected in to teams, the best students tend to cluster, leaving the weak ones to shift for themselves, and friends cluster, leaving some students out of groups and excluding others from cliques within groups.

When laboratory assistances form a group based on their alphabetical order of names, non-heterogenous group formed. Moreover, when graduates go to work in industry or business, they will be required to work in teams and will have no voice in the team formation, and their job performance evaluation will depend as much on their ability to work with their team mates as on their technical skills.

Typically each laboratory completed requires a report; this weekly report submission places an emphasis on submission at any cost rather its accuracy and the non-copy of other groups, consequently a trend of quantity rather than quality is observed. Therefore, criteria’s must be selected and introduced to students at the beginning of the laboratory.
B. Implementation

Proposed Action for Pre-Laboratory Flow Charts

Students worked in teams of five or six on activities that involved laboratory works and most activities focused on a many practical skills and could be completed in 3 hours session for a single experiment is common in Haramaya university chemistry department due to the large number of students, lack of resources like chemicals, instruments and work places. However, it is possible to reduce this problem by engaging all students to the pre-laboratory flow charts. Therefore, the best pre-laboratory flow charts each group members were selected by respective group members and submitted for laboratory assistances. Then the best pre-laboratory flow charts of each group were evaluated and the results were posted to all students to create a competitive spirit among individuals and groups.

Cooperative Learning

Students working alone may tend to delay completing assignments or skip them altogether, but when they know that others are counting on them, they are motivated to do the work in a timely manner [9].

Individual student performance was superior when cooperative methods were used as compared with competitive or individualistic methods. The performance outcomes measured include knowledge acquisition, retention, accuracy, creativity in problem solving, and higher-level reasoning. According to the Johnson & Johnson model, cooperative learning is instruction that involves students working in teams to accomplish a common goal, under conditions that include the following elements [10].
Laboratory Assistances were form teams based on their semester average grade rather than permitting students to choose their own team mates. The criteria were selected and used for team or group formation for doing experiments [10].

When students work in pairs, the diversity of ideas and approaches that leads to many of the benefits of cooperative learning may be lacking. In teams of 8 or more, some students are likely to be inactive unless the tasks have distinct and well-defined roles for each team member. The unfairness of forming a group with only weak students is obvious, but groups with only strong students are equally undesirable. The members of such teams are likely to divide up the homework and communicate only cursorily with one another, avoiding the interactions that lead to most of the proven benefits of cooperative learning. In heterogeneous groups, the weaker students gain from seeing how better students approach problems, and the stronger students gain a deeper understanding of the subject by teaching it to others.

Assigning different roles to team members (as coordinator, recorder, checker, group process monitor), rotating the roles periodically or for each experiments. The coordinator reminds team members of when and where they should meet and keeps everyone on task during team meetings; the recorder prepares the final solution to be turned in; the checker double-checks the solution before it is handed in and makes sure the assignment is turned in on time.; and the monitor checks to be sure everyone understands the solutions and the strategies used to get them. In teams of 5, the coordinator may also assume the duties of the monitor.

Give a bonus on each experiment (typically 1-2 points) to all members of teams with average test grades above rather accounting the attendance during each laboratory classes. The bonus should not be tied to each person on the team getting a certain grade, which would put too much pressure on weaker members of the team and make it impossible for teams with one very
weak student to ever get the bonus. Linking the bonus to the team average grade gives all team members an incentive to get the highest grade they can and motivates the stronger students to tutor their team mates.

Give individual tests that cover all of the material on the team assignments and experiments. Tests or laboratory analysis questions were frequently given for individual group members. Make someone on the team (the process monitor) responsible for ensuring that everyone understands everything in the report or experiments that the team hands in. The monitor should also make sure everyone participates in the team deliberations and that all ideas and questions are heard. Make teams responsible for seeing that non-contributors don’t get credit. A policy those only contributors’ names should go on assignments and reports were announced at the beginning of the course, and reminders of the policy should be given to students complaining about hitchhikers on their teams. Most students are inclined to cut their teammates some slack initially, but if the hitchhikers continue to miss meetings or fail to do what they were supposed to do, eventually the responsible team members get tired of being exploited and begin to implement this policy.

Implementing Post Laboratory Report Writing and Presentation Evaluation and Checklist

All students were engaged to laboratory experiments as stated above and the post laboratory reports were submitted at the end of each experiment before starting the next experiment and evaluated based on the curricula designed. The presentation was arranged for each group and the tasks were assigned to each individual.

The checklist is designed to assist you to write a complete, professional-quality report. It will help you to ensure that all essential information is included in the appropriate place, and that
the report has been prepared in the proper format. Careful use of the checklist will result in better grades. Students must submit a completed, signed checklist with each report.

The grades have been paid special attention to the checklists. The following rules were applied:

- A report submitted without a checklist attached at the front was not graded; and no credits were given for that report.
- If an item on the list is not checked, this will indicate to the grader that it has not been addressed in the report, and the appropriate number of points will be deducted.
- If an item has been checked, but has been covered only partially, or incorrectly, the report, partial credit will be given with an explanation of the omission or error.
- If an item has been checked but it has not been addressed in the report, grading was discontinued, and no credit will be given for the report, on grounds of unethical behavior.

C. Action Evaluation

The collected data from each of the above procedure were evaluated as to prove the effectiveness of pre-laboratory flow charts, post implementation questionnaire and report writing with presentation on the achievement of year one practical organic chemistry I students. The results were tabulated and analyzed as follows.

Table 1: Pre-laboratory flow charts check lists and evaluations 2.0% for each experiment.

<table>
<thead>
<tr>
<th>Group No</th>
<th>Exp’t No 1</th>
<th>Exp’t No 2</th>
<th>Exp’t No 3</th>
<th>Exp’t No 4</th>
<th>Exp’t No 5</th>
<th>Exp’t No 6</th>
<th>Exp’t No 7</th>
<th>Exp’t No 8</th>
<th>Exp’t No 9</th>
<th>Exp’t No 10</th>
<th>Total 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7.5</td>
</tr>
<tr>
<td>3</td>
<td>0.25</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6.75</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7.75</td>
</tr>
<tr>
<td>7</td>
<td>0.25</td>
<td>0.75</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8.25</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7.25</td>
</tr>
<tr>
<td>9</td>
<td>0.25</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>0.75</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8.25</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Exp’t: Experiment
According to the data tabulated above, the performance of each group increased. However, this increment comes from the competition among individuals in respective group members and in the groups. The competitions in each group members were formed by selecting the best flow chart from each group members to compete with others and competition among the groups were formed by showing their result on notice board arranged from the higher to lower. The low achievers were ashamed with their mark and planned to become the first for the next work. Even if some group members were not to bring the pre-laboratory activities for experiment number one and two, then they believed that not doing the pre-laboratory flow charts may affect their grade. Taking an attendance for the students presence were common earlier, but now, they exposed to do pre-laboratory flow charts which make them aware of what will be done in the laboratory and evaluated by their flow chart diagrams 10% instead of accounting 10% for their presence. Generally, this way of evaluation was considered as very useful for practical organic chemistry courses.

Table 2: Post implementation (action Evaluation) questionnaire responded by students

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
<th>No of respondents</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you participate in doing experiments during organic laboratory regularly?</td>
<td>50 0</td>
<td>Yes No Yes No</td>
</tr>
<tr>
<td>2</td>
<td>Have you brought pre lab activities and flow charts to the class before starting experiments?</td>
<td>50 0</td>
<td>100% 0</td>
</tr>
<tr>
<td>3</td>
<td>Do you contribute in laboratory report writing?</td>
<td>50 0</td>
<td>100% 0</td>
</tr>
<tr>
<td>4</td>
<td>Are you interested in organic laboratory class with new approach of cooperative learning?</td>
<td>47 3</td>
<td>94% 6%</td>
</tr>
<tr>
<td>5</td>
<td>Do all your group members engaged in all experiments?</td>
<td>50 0</td>
<td>100% 0</td>
</tr>
<tr>
<td>6</td>
<td>Did your group member rotate the responsibility for each experiment which assigned in different roles to team members (as coordinator, recorder, checker, group process monitor)?</td>
<td>48 2</td>
<td>96% 4%</td>
</tr>
</tbody>
</table>

Total number of students responded for pre implementation questionnaire 50
According to the response of students about cooperative learning, six (6) post implementation questions which were similar to pre implementation questions were considered and administered for students. The response of each items of questions were discussed as follows.

As shown in table 2 items number 1 and 2, all of the students were participated in doing experiments during laboratory regularly and bring pre laboratory activities and flow charts before starting experiments.

Among 50 students, 94% of them were interested in practical organic chemistry with the new approach of cooperative learning and the rest students still not interested. In addition to this, all of them were contribute in laboratory report writing and engaged in all experiments. But, 4% of the total students were not rotate the roles to be responsible for each experiments which assigned in different roles to their team members as coordinator, monitor, checker and recorder one role for a single experiment.

Table 3: Laboratory report evaluation and presentation results 5% for each experiment

<table>
<thead>
<tr>
<th>Group No</th>
<th>Exp’t No 1</th>
<th>Exp’t No 2</th>
<th>Exp’t No 3</th>
<th>Exp’t No 4</th>
<th>Exp’t No 5</th>
<th>Exp’t No 6</th>
<th>Exp’t No 7</th>
<th>Exp’t No 8</th>
<th>Exp’t No 9</th>
<th>Exp’t No 10</th>
<th>Total 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4.5</td>
<td>3.5</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
<td>3.5</td>
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<td>5</td>
<td>4</td>
<td>44</td>
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<tr>
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<td>5</td>
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<td>5</td>
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<td>4</td>
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<td>5</td>
<td>43.5</td>
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<td>5</td>
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<td>4.5</td>
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<td>3.5</td>
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<td>5</td>
<td>41.5</td>
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<td>4.5</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
<td>5</td>
<td>4.5</td>
<td>45.5</td>
</tr>
</tbody>
</table>

As shown in the above table, the laboratory reports were evaluated based on criteria which indicated in appendix-D and from the evaluated results, some groups like group number 10, 2, 5, and others may have the possibility in falling “A” grade range. But this may happen if they answer the final examination which will be accounted out of 40% relatively.
CONCLUSIONS

Students typically arrive at the laboratory to carry out an experiment without a very clear idea of the practical techniques they were using in the laboratory, the practical skills they will need, or the chemistry which underlies the practical. It is usually only after the laboratory, during a write up, that students were generally start to work out what it was they had been doing all day. This is obviously an unsatisfactory experience and students were clearly got much more from their laboratory work if they know what they were doing beforehand. Pre-laboratory preparation was the key to achieving this therefore been to shift the balance of work outside the laboratory to before rather than after the practical class so that students were much better informed and more confident.

It is believed that the pre-laboratory flow charts, cooperative learning and post laboratory report writing method pedagogies could strongly impact on practical organic chemistry I classes by providing students with both a real-world context for the chemical principles and a more accurate portrayal of the way that modern science is practiced. The collaborative nature of the pre-laboratory flow charts, cooperative learning and post laboratory report writing methods creates a better working atmosphere for all students in this action research. We have also found that the pre-laboratory flow charts, cooperative learning and post laboratory report writing methods bring students from a variety of backgrounds to the same level of class involvement, which is especially important in classes that include both students who have taken advanced placement chemistry and those who have not taken chemistry previously. Most importantly, by simulating the experiments to the scientific problem-solving process in the classroom, students gain an understanding of what it means to think like a chemist and gain confidence in their ability to carry out those thought processes or reactions and products. The cooperative learning was an ideal pedagogy for
demonstrating to students the interaction of science, technology, and society, and it allows them to develop a sense of the social impact of science-related decisions.

Thus, cooperative learning refers to work done by student teams producing a product of some sort such as a laboratory report, or the design of a product or a process, under conditions that satisfy five criteria: (1) positive interdependence, (2) individual accountability, (3) face-to-face interaction for at least part of the work, (4) appropriate use of interpersonal skills, and (5) regular self-assessment of team functioning [10]. Extensive research has shown that relative to traditional individual and competitive modes of instruction, properly implemented cooperative learning leads to greater learning and superior development of communication and teamwork skills (e.g. leadership, project management, and conflict resolution skills). The technique has been used with considerable success in all scientific disciplines, including chemistry.

Most importantly, instructors or laboratory technicians who are successful in using cooperative learning in their classes will have the satisfaction of knowing that they have significantly helped prepare their students for their professional careers. No one said anything negative about group work or cooperative learning; although three respondents indicated that they disliked it. Practitioners don’t guarantee a retrospective evaluation this positive to everyone who uses cooperative learning, but we believe the possibility of it makes the effort worthwhile.

The post-laboratory report writing also needs careful thought. Imaginative post-laboratory exercises were used. These allowed students opportunities to apply the ideas they had learned, as well as offering some insights into their understanding. A range of ingenious post-laboratory exercises in practical organic chemistry I class were considered very valuable when the students report evaluated.
Using different active learning methods especially pre-laboratory flow chart evaluation and check lists, cooperative learning and post laboratory report writing evaluation and presentations in practical organic chemistry I class and other laboratory classes are possible. By using these methods we have seen astonishing results in organic chemistry I laboratory class and some of the results are obtained by changing the older mode of teaching to modern active learning methods. Furthermore, the students who were taught in the active-learning mode did much better in practical organic chemistry I laboratory sections of this course, in addition to its academic advantages, active learning has been shown to produce numerous social and psychological benefits observed students attitude towards the subject. As a recent review of research on cooperative learning found that it boosts development of critical-thinking skills and fosters social interdependence and support among students. Therefore, if any laboratory technicians or laboratory teachers apply this basic work, they will develop a well-mannered chemist professional.

University faculties sometimes feel that although active learning may work in some fields, it probably would not work in their field. The fact that practical organic chemistry could successfully employ the techniques described in this paper speaks well for the universality of this teaching pedagogy.

This paper makes a practical application for the students’ achievement and performances. Generally, this paper confirms that practical organic chemistry I class students obtained particularly:-

- Skills relating to learning making chemistry real, illustrating ideas, empirical testing ideas, teaching new ideas,
- Practical skills handling equipment and chemicals safely, measuring and observing carefully,
✓ Scientific skills learning skills of deduction and interpretation, seeing a science at work, devising experiments, and

✓ General skills team working, reporting, presenting and discussing, developing ways to solve problems.

REFERENCES
2. Morrell J.B., (1972). The chemistry breeders, the research schools of Liebig and Thomas Thomson. AMBIX, 19, 1-47.

ACKNOWLEDGMENT
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APPENDICES
Appendix A: Pilot test questionnaire response of students

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
<th>No of respondents</th>
<th>% of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you participate in doing experiments during organic laboratory regularly?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Yes</td>
<td>10</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>B. No</td>
<td>40</td>
<td>80%</td>
</tr>
<tr>
<td>2</td>
<td>Do you contribute in laboratory report writing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Yes</td>
<td>19</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>B. No</td>
<td>31</td>
<td>62%</td>
</tr>
<tr>
<td>3</td>
<td>Have you brought pre-laboratory activities and flow charts to the class before starting experiments?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Yes</td>
<td>6</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>B. No</td>
<td>44</td>
<td>88%</td>
</tr>
<tr>
<td>4</td>
<td>Who is responsible in forming groups for laboratory work?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Laboratory assistances based on alphabetical order</td>
<td>26</td>
<td>52%</td>
</tr>
<tr>
<td></td>
<td>B. Students based on their team mate</td>
<td>24</td>
<td>48%</td>
</tr>
</tbody>
</table>

Total number of students responded for pre-implementation questionnaire 50

Appendix B: Post implementation questionnaire used for action evaluation

<table>
<thead>
<tr>
<th>No</th>
<th>Items</th>
<th>No of respondents</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you participate in doing experiments during organic laboratory regularly?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>50</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Have you brought pre lab activities and flow charts to the class before starting experiments?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>50</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Do you contribute in laboratory report writing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>50</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Are you interested in organic laboratory class with new approach of cooperative learning?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>47</td>
<td>94%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>3</td>
<td>6%</td>
</tr>
<tr>
<td>5</td>
<td>Do all your group members engaged in all experiments?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>50</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Did your group member rotate the responsibility for each experiment which assigned in different roles to team members (as coordinator, recorder, checker, group process monitor)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>48</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

Total number of students responded for pre implementation questionnaire 50
Appendix C: Flow charts sample
The African Journal of Chemical Education (AJCE) is a biannual online journal of the Federation of African Societies of Chemistry (FASC). The primary focus of the content of AJCE is chemistry education in Africa. It, however, addresses chemistry education issues from any part of the world that have relevance for Africa. The type of contents may include, but not limited to, the following:

**RESEARCH PAPERS** reporting the results of original research. It is a peer-reviewed submission that deals with chemistry education at any level (primary, secondary, undergraduate, and postgraduate) and can address a specific content area, describe a new pedagogy or teaching method, or provide results from an innovation or from a formal research project.

**SHORT NOTES** containing the results of a limited investigation or a shorter submission, generally containing updates or extensions of a topic that has already been published.

**REVIEWS** presenting a thorough documentation of subjects of current interest in chemical education.

**LABORATORY EXPERIMENTS AND DEMONSTRATIONS** describing a novel experiment/demonstration, including instructions for students and the instructor and information about safety and hazards.

**SCIENTIFIC THEORIES** describing the scientific, historical and philosophical foundations of theories and their implications to chemical education.

**ACTIVITIES** describing a hands-on activity that can be done in the classroom or laboratory and/or as a take home project.

**INDIGENOUS KNOWLEDGE AND CHEMISTRY IN AFRICA** as a special feature that addresses the relationship between indigenous knowledge and chemistry in Africa. It could be in the form of an article, a note, an activity, commentary, etc.

**LETTER TO THE EDITOR:** A reader response to an editorial, research report or article that had been published previously. The short piece should contribute to or elicit discussion on the subject without overstepping professional courtesy.

All manuscripts must be written in English and be preferably organized under the following headings: a) **TITLE**, Author(s), Address(es), and **ABSTRACT** in the first page, b) **INTRODUCTION** reviewing literature related to the theme of the manuscript, stating the problem and purpose of the study, c) **METHODOLOGY/EXPERIMENTAL** including the design and procedures of the study, instruments used and issues related to the reliability and/or validity of the instruments, when applicable, d) **RESULTS AND DISCUSSION**, e) **REFERENCES** in which reference numbers appear in the text sequentially in brackets, each reference be given a separate reference number, *et al* and other notations like *Ibid* are avoided, and finally f) **ACKNOWLEDGEMENTS**.

When submitting a manuscript, please indicate where your manuscript best fits from the above list of categories of content type. All enquiries and manuscripts should be addressed to the Editor-in-Chief: email **eic@faschem.org**, PO Box 2305, Addis Ababa, Ethiopia.