The Impacts of Modified Guided-Discovery Methods and Some selected covariates on Pre-service Teachers' Learning Outcomes and Motivation in Physics Laboratories

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Abstract

The objectives of this study were to compare pre-post test within group in terms of dependent and covariates, and measures the contribution of covariates on significant dependent variable/s in each group. Dependent variables used in this study are conceptual and procedural knowledge, views of nature of science and process skills (NOS and PS), and motivation. Similarly, the covariate variables are pedagogical and forms of laboratory orientation, practicing of process skills, and academic performance (CGPA). To achieve objectives, the study developed five alternative models of learning that guides selection and integration of generic components in physics laboratory. In addition, pedagogies used in physics laboratory, especially guided-discovery modified and levelled into three alternative approaches. Moreover, an alternative approach developed to derive and select dependent and covariates from generic components of physics laboratory session. The study implemented four models of learning in physics laboratories of colleges of teachers' education. Tandem design phase III with quasi-experimental approach employed. Comparative and association studies used to measure objectives of the study. Convenience, purposive, and random samplings used to select study subjects. The result indicates, all modified guided-discovery methods had significant impact on procedural knowledge, and had positive impact on conceptual knowledge, and motivation. All implemented pedagogies such as conventional and three modified guided-discovery methods had positive impact on all covariate variables. The association study indicated that, there is contribution of covariates on significant dependent variables in each group, however the effect is small. Generally, the study finding indicates that, alternative integration of generic components, and using modified guided-discovery methods in physics laboratory had positive impact on students' procedural and conceptual knowledge, and motivation. In addition, different types and levels of association among dependent and covariate variables obtained. However, to enhance students' views of NOS and PS may improve study design and/or modifying college curricula suggested.

Key words: *Conceptual knowledge, Modified guided-discovery, model of learning, motivation, procedural knowledge, views of nature of science*

1. Introduction

In developing science, especially physics education curricula, integrating generic components and its implementation needs special focus. In addition, addressing an alternative method/s to attain the intended objectives required [1].The reason is that, appropriate integration of generic components and implementation had significant association with students' learning outcomes and motivation [2]. As there are strong side of materials developed for science subjects used in schools, colleges and universities, there are also limitations in science/physics education curricula materials (course modules and laboratory manuals) in terms of appropriate integration of generic components and its implementation. If science curricula materials such as text books, modules, and laboratory manuals used in universities, college, and schools not appropriately integrate the generic components of science and implemented, it may have negative impact on students learning outcomes and motivation. Thus, integration of generic components of science subjects and its implementation needs special focus, however less work done[2]. As noted by Andinet, Said, & Endris, et als[3] , Tolessa & Muhammed[4], and Oli[5] students' performance in science (physics) is very low. Similarly, Baloyi, Meyer, & Gaigher[6] noted that, even though educational polices and curricula materials state excellent learning outcomes in terms of concepts, procedures, and natures of science, but these outcomes less achieved by many of the students. Moreover, Ramarian[7] and Blanchard, Annetta, & Southerland[8] identified, the problem related to science education concern not only students but also schoolteachers have no clear ideas about how science operates or how scientific knowledge developed. In context of Ethiopia, students in schools and colleges have the same problem [9],[4]. Some of the causes for these gaps are related with integrations and implementation of generic components in science lessons. Therefore, special focus needed in developing science education curricula in terms of integrating generic components and its appropriate implementation.

Science/physics education research findings recommend, curricula materials in science education should integrate basic components of science such as process skills, concepts, nature of science, alternative pedagogy, forms of laboratory, and assessment mechanisms[10],[11]. Also as noted by Badri & Shri [1] science education curricula should includes the basics components related to cognitive, content, process, historical, environmental, and ethical aspects. The reason is that, well-integration and appropriate implementation of the basic components in science let students easily acquire knowledge about concepts in science. Moreover, it helps to constructs an alternative knowledge about the real picture of what scientists doing in investigating scientific findings. This also used to understand nature of science, and motivate students to learn science [12]. Despite the fact that, the area needs critical focus, but less work done [6],[10].

In science education, laboratory work had significant impact on students' practicing of science process skills, in cultivating alternative knowledge construction, understand about science and expose students to different forms of learning environment[4] , [13], [14], [15]. Consequently, activities conducted in science laboratory let students manipulate real objects and materials; develop the art of experimentation, and analytical skills. In addition, it used to easily understand concepts, nature of science, and develop interest (motivation) towards science [6], [16], [17], [18], [19]. This implies that there is direct association of student learning outcomes, integration, and implementations of generic components in science (physics) laboratory work[2]. Due to these, laboratory work in science education is used as student-centred instructional methods that encourage learners to be active rather than passive [19]. Therefore, in science education, absence of laboratory work affects quality of science education particularly biology, chemistry, and physics [3], [4]. Thus, to sustain quality science education, laboratories work lessons should integrate generic components in its instruction [1],[14].

Though Ethiopian education polices and global studies advocated science laboratory work in upper primary schools and colleges, however it less implemented in schools and colleges. In context of Ethiopia, laboratory works implemented in a few schools of urban areas [4]. Though, science/physics laboratory implemented in colleges, but dominantly it perceived as supplement for science/physics contents being taught during lecture [6], [19]], [20]. Even though there are supplementary and/ or complementary laboratory works in colleges of teachers' education, but the curricula related to laboratory work had limitation in terms of integrating generic components and gaps in its implementation. Due to these limitations supplementary approach is dominant[4], [9], [19], [21]. As noted by Tesfaye [22], even though college of teacher education aim to teach science and how to teach science, but materials designed for these purposes focus more on content knowledge. In addition, the materials used in science laboratory are structured (cookbook), and forms of laboratory used is confirmatory [19]. The materials missing contents related to PS and NOS, no allocated forms of laboratory and pedagogy to conduct each experiment. Similarly, in laboratory curricula there are no model of learning addressed that guides selection and integration of generic components, and assessment mechanisms used for each method [2]. In context of Ethiopia, the college curricula materials are designed by instructors/teachers in college. However, the designed materials have limitations of integrating generic components in science such as pedagogy, forms of laboratory, contents, NOS and PS being taught, and assessment mechanisms [2]. The background factors that may cause limitations in material development are: teachers may have pressure to complete contents [23], teachers may have no instructional knowledge to incorporate and teach about NOS and PS [24]. Moreover, according to Aweke, Eyasu, Kassa, Mulugeta, & Yenealem [25] the policy debates about concurrent and consecutive approach of pedagogy and contents are challenges.

Due to these limitations in materials and in teachers, teachers are forced dominantly to use didactic method of teaching in colleges and/or in schools [9],[10],[26]. In addition, dominantly implemented confirmative forms of laboratory[19]. However, this traditional method of teaching and confirmative laboratory approach are strongly criticized as they are ineffective [4],[11]. As result of these limitations, majority of students have limitations in procedural knowledge, practicing process skills, on views of nature of science, and motivation towards science/physics [3], [5]. In addition, they have poor scientific reasoning ability, and less motivation to conduct laboratory activities [3], [14].

In addition to integration of generic components and implementation of generic components of physics laboratory sessions, in context of Ethiopian college of teachers' education, there are gaps in material development process [2],[9]. The main limitations are less clear standardized directions set for material development for college of teacher education from central government, due to weak connection between minster of education of Ethiopia and regional states in terms of colleges of teachers' education [9]. The reason is that college of teachers' education are governed by regional states. As result of this, there is less clear model of integrating contents, process skills, and nature of science observed in laboratory lessons. In addition, less standard assessment model used to measure laboratory sessions. Moreover, there is less clear type of pedagogy and forms of laboratory addressed to conduct experiments.

Even though there are many study trends in laboratory works, but most are focused on implementation of some selected pedagogy and measure its impacts on students learning outcomes and motivation [1], [6],[27], [28]. In addition, there are studies which are comparing the impacts of different forms of laboratories on students' learning outcomes and motivation [7], [8], [29],[30],31,[32]. Similarly, implicit or explicit approach of NOS and PS in science laboratory work are mostly implemented area of study [33]. Fewer works conducted on critique on laboratory works and content analysis about science/physics laboratory materials [10], [19].

In the above most studies and in science/physics education curricula used in college of teachers' education, there are gaps related to integration of generic components, and its implementation. The study findings by Hofstein &Lunetta [34] indicted that, most studies have focused on few laboratory related skills that failed to describe student abilities and attitudes, and standardized achievement tools were used which were not specifically designed to measure laboratory outcomes. In addition, more emphasis was on testing factual or conceptual knowledge, and that not look at the teacher behaviour. Moreover, experiments are too inductive or deductive, and the role of laboratory manual not studied. Again, Hofstein &Lunetta [10] identified that, the science laboratory works ignore the affective variables such as attitudes and interest. In addition, there are limitations in measuring the impacts of science laboratory work on hypotheses and questions generating ability of students, and the assessment had done using conventional ways and large discrepancies between learning goals and actual learning in laboratory classes. The content analysis conducted by Shimeles[19]in physics laboratory materials(manuals) indicated that, there is ignorance of affective variables such as attitudes and interest, discrepancies between learning goals and actual learning in laboratory classes, and gaps in integrating generic components related to process skills. Moreover, the materials were more of content centred and designed for conventional methods and confirmatory form of laboratory.

In addition to the above-identified gaps, the literature and college laboratory overview conducted by [2] indicated that, there is no clear model of learning that guides selection and integration of pedagogy, forms of laboratory, and assessment mechanisms used in physics laboratory curricula. In addition, in terms of pedagogy, in many studies guided-discovery method used as single phase of constructive instructional approach in science/physics laboratory. Moreover, there is no clear model used to drive and select dependent and covariates when conduction studies in science laboratory work. Due to these limitations, there is mismatch between the independent variables used (generic components of laboratory) and their impacts on students learning outcomes and motivation. As result of these limitation there is unclear debate about the success of pedagogies, forms of laboratory, and different approaches of NOS and PS in science/physics laboratory work [2]. Therefore, it is critical to minimize these gaps in science/physics education laboratory work. Thus, this study has an alternative approach to minimize the gaps/ limitations in the area of study. The study proposed an alternative model of learning that guides selection and integration of pedagogy and forms of laboratory in science/physics education laboratory. In addition, modified guided-discovery method into three alternative approaches (see fig-1). Moreover, proposed an alternative method to derive and select dependent and covariates to conduct study in science laboratory work(table-1), and addressed clear explicit integration of contents, NOS, and PS(see table-2).

To conduct the above mentioned activities, the study designed the following conceptual framework that guides this study. First, theories of learning overviewed in terms of their implication for science laboratory work. Based on the implications of theories of learning, models of learning that guides selection and integration of pedagogy and forms of laboratory (generic components) developed. Second, pedagogies and forms of laboratory used in science/physics education laboratory overviewed. That leads to modify guided-discovery into three alternative approaches (see fig-1). In addition, triangulation of model of leaning, pedagogy, and forms of laboratory conducted. Third, based on gaps in literature and current physics laboratory curricula, model lesson plan developed that includes model of learning, pedagogy, forms of laboratory, contents, NOS and PS. Moreover, an alternative approach developed to derive and select dependent and covariates derived from generic components of physics laboratory session. Finally, by selecting some models of learning, implementation study conducted in college of teachers' education physics laboratories.

Based on the above conceptual frame work, the basic theories of learning overviewed in this study are behaviourisms, cognitive, social-cognitive, and constructivism. The overview conducted focused on implication of theories of learning for science/physics education laboratory work. The literatures overviewed are[35], [36],[37],[38],[39],[40],[41],[42],[43],[44]. The overview result indicated that, behaviourism is focused on measurable behaviour such as knowledge, skill, and affective domains that achieved by using structured forms of curricula and controlled/confirmatory approach of laboratory. That gives a hind how to develop structured curricula and forms of laboratory to train measurable behaviour. Similarly, the implications obtained from cognitive is, it focused on processing or on practicing of process skills. That give a hind how to develop process based curricula/instruction and forms of laboratory to train measurable behaviour. In addition, the implications obtained from social-cognitive indicates, it focused on observational modelling. That gives a hint how learning occurred by starting with observation (by demonstration), and end up with the alternative highest level of modelling. Moreover, the implication obtained from constructivism indicates that, it focused on construction of an alternative knowledge about phenomena via social discourse. That gives a clue how social discourse support learning and used as a means to construct an alternative knowledge [2]. Then, based on the above basics of theories of learning, the models of learning that used as guide to develop instruction and conduct assessment in science/physics laboratory work from more complex to simple are:

1. An alternative knowledge can be constructed in science/physics laboratory by using open contents/curricula and open form of laboratory.
   In this model students confront to practice process skills such as pose questions, propose hypothesis, and develop design/method---etc. In addition, construct alternative knowledge by themselves with a few support of teacher. Because of students have freedom to think, pose question, develop methods, trial and error (do- rethink- re-correct), students be creative and construct an alternative knowledge.
2. Knowledge can be acquired and/ or an alternative knowledge can be constructed in science/physics laboratory by using semi-structured curricula/content and semi-structured form of laboratory.
   This model is free for both teacher and student. There is no obligatory starting point for teacher and students. However, may the objective of curricula or problem lead both teacher and students to interact. In all initiated (teacher, student, curricula) cause, teacher scaffold and withdraw at the level when students reach to the level they can do things by themselves. In this model, students acquired and or construct an alternative knowledge by social discourse with each other, with the teacher both in practice and in theory. Teacher may demonstrate or inject concept, and pose questions. Thus, both curricula/content and forms of laboratory are semi-structured.
3. Knowledge can be acquired and/ or an alternative knowledge can be constructed in science/physics laboratory by using semi-structured curricula and structured /controlled form of laboratory.
   In this model the content is semi-structured, but laboratory is structured (teacher demonstrate the activates conducted in laboratory). Students confront to practice process skills by redesign or modify methods, based on teacher's demonstration, then manipulate materials, collect their own data, finally construct or confirm with theories.

4. Knowledge can be acquired and/ or an alternative knowledge constructed in science/physics laboratory by using structured curricula/content and using uncontrolled form of laboratory. In this model content, PS, NOS and PS structured, but laboratory is open. Due to uncontrolled/open form of laboratory, students confront to challenges of practicing process skills such as manipulate materials, collect their own data, compare theory based on experimental result. Finally based on data give their own conclusion. Thus, concept injected and open laboratory used to reinforce an alternative knowledge construction and/ or confirm with theory are instructional approach.
5. Knowledge can be acquired or confirmed in science/physics laboratory by using structured contents/curricula and controlled form of laboratory.
   In this model contents, PS, NOS and PS pre-decided/structured and forms of laboratory is confirmatory. Thus, lesson includes well-explained theory (content) and structured form of laboratory, that help students exercise the activities and confirm with theory [2].

The overview of pedagogies and forms of laboratories used in science laboratories indicates that, the most known pedagogies used in science education laboratories are conventional (lecture and/ or demonstration), guided-discovery, and free discovery [6],[45],[46]. However, in science laboratory guided-discovery suggested, because it has the middle ground effect of both traditional and free discovery method [45]. In most studies, guided-discovery considered as single phase of instruction, but it has three alternative approaches. In this study they were obtained by merging activities from traditional and free discovery. They are structured guided-discovery (SGD), semi-structured guided-discovery (SSGD), and scaffolding guided-discovery (SCGD) methods. The following figure (Fig-1) more illustrate how they obtained by merging traditional either in lecture or demonstration with activities from free discovery (practicing of process skills). The background theory supports this modification of guided-discovery is self-determination [47],[48]. According to this theory, students have needs of proficiency, independency, and connection, which require attention of the teacher. In all guided-discovery methods, the connection of teacher with student is strong relative to free discovery, and balanced relative to traditional method. The reason is that, the method gives an opportunity for independency, proficiency, and connection with teacher.

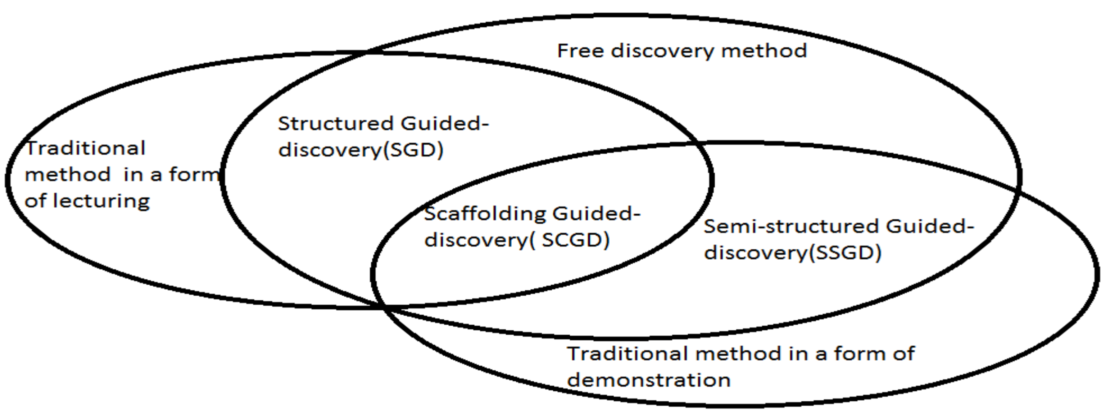

Fig.1. Modification of guided-discovery methods from conventional and free discovery methods.

From the figure above we can see that, structured guided-discovery (SGD) obtained by merging lecturing from traditional method and discovery activities(practicing process skills) from free discovery method. In this method, knowledge acquired and/ or constructed by using structured curricula/content and open/uncontrolled forms of laboratory. Since, structured curricula gives more emphasis to structured mind set up/schema, but to conduct discovery activities (practice PS) open laboratory selected to this level of guided-discovery. Therefore, the mode of instruction suggested is to start with lecture/concept injection, and pose problems, but answer to posed problem/solutions reached by using open laboratory that encourages discovery activities. Similarly, semi-structured guided-discovery (SSGD) obtained by merging demonstration from tradition method with discovery activities from free discovery. In this method, the knowledge acquired and/ or constructed by semi-structured curricula (by demonstration) and structured form of laboratory. In this approach, schema or emerging knowledge constructed from the demonstration. Based on demonstration learners answer posed questions, and conduct the discovery activities. Demonstration offers some insight into learners to practice process skills and interpretations [49]. Therefore, mode of instruction starts with demonstration, and pose problem. Students are expected to construct theory, and may re-set the arrangement of equipment to answer posed problems.

The last modified guided-discovery method is scaffolding guided-discovery (SCGD), which obtained by merging activities from traditional method either in a form of lecturing and/ or demonstration with activities from free discovery. This method is open for both teacher and students. There is no specific starting activity conducted by teacher and/or students, however the objective of curricula, problem at hand let start to laboratory work. Thus, both content/curricula and forms of laboratory are semi-structured. The instruction may start with pose problem (both by teacher or students), concept injection and / or demonstration (by teacher), then any scaffolding activities conducted by the teacher, then gradually withdrawn. This approach encourages students to do things and construct their own meaning [45] , [49]. This method, confront students to design the method, and answering/solved the problems, then independently report their work at the end [2].

The overview of forms of laboratory indicates that, there are different arrangements of laboratory in science education that design in terms of engagement of teacher and learners. According to Boud, et al [50] forms of laboratory classified into three levels such as: to conduct controlled exercise, to conduct experimental investigations, and to conduct research project. Similarly Wooloough [51] , divided it in to four types such as to excise (to practicing skills), to experience (to fell the phenomena), to demonstration (develop the argument or create impression), and to investigations (hypothesis-testing and problem solving). Tamir [52] classified laboratory work in to four levels, such as: level-0, 1, 2, and 3 based on the support given to the students by the teacher in a form of pose question, design methods, and answering the questions. However, there are gaps in all scholars' division such as they not explicitly allocate what pedagogy fit for each form of laboratory. In addition, they not indicated model of learning that guides selection and integration of generic components in each levels and types of forms of science laboratory. However, based on practicing of science process skills, acquiring and/ or constructing an alternative knowledge science laboratory works classified in to three forms such controlled (structured), partially controlled (semi-structured), and uncontrolled/open or free [19], [37], [53].

Based on the overview of theories of learning, pedagogies, and forms of laboratory the following is the triangulation of three generic components in science laboratory.

1. Model-1 best fit for free discovery method and open forms of laboratory
2. Model-2 best fit for scaffolding guided –discovery and semi-structured forms of laboratory
3. Model-3 best fit for semi-structured guided-discovery and structured forms of laboratory
4. Model-4 best fit for structured guided-discovery and open/uncontrolled forms of laboratory
5. Model-5 best fit for conventional method and controlled forms of laboratory [2].

In this study models 2,3, 4 and 5 implemented. The reason is that, model-1 criticized as it needs high cognitive level of practicing scientific process skills, and increase cognitive load of learners [54]. Because, implementing free discovery/exploration learning is difficult to implement on beginning learners with limitation in practicing process skills, the reason that they may have no necessary skills to integrate the new information with information they have learned in the past [55]. Thus, according to Baloyi, et als[6], Mayer [45], Kirschner et als[54], guided-discovery method suggested as method of instruction used in science/physics laboratory. Therefore, Model two, three, and four are alternative approaches of guided discovery. The detail presented in table-1 below.

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Table.1. The alignment of generic components in science/physics laboratory sessions.

		The Components of lessons and its presentation in physics laboratory				
Pedagogies used in physics laboratory		Forms of laboratory fit for the pedagogy	Model of learning that fit for the pedagogy and forms of laboratory from simple to complex	Presentation of contents, NOS and PS	Presentation of question and answer for the question	Assessment used both formative and/ or summative
Traditional/conventional method		Structured with detail steps in lab manuals, and set equipments in laboratory for the experiment	Model-5	-Contents explicitly present by using lecture/ demonstration - PS, explicitly presented - NOS, implicitly in activity-based approach	Teacher pose questions , but in advance answers known	More focused on acquired form of knowledge, in terms of contents, process, and NOS. Mostly used objective type.
Modified guided discovery methods	Structured guided-discover (SGD)	Open, however guide lines about the how to set apparatus/ experiment in diagram given	Model-4	-concepts injected (highlight/ lecture) - PS, explicitly presented by lecture - NOS, implicit activity-based approach	Teacher pose problem, and answer to the questions are based on data propagated from the lab work and injected concepts	Focused on both acquired and/ or alternatively constructed knowledge. Thus, any type assessment tools can be used, that can measure contents, process, and NOS and PS
	Semi-structured guided-discovery (SSGD)	Structured (demonstrate how to set up of laboratory materials)	Model-3	-concept injection by demonstrative -PS, explicitly presented by lecture - NO, implicit activity-based approach	Teacher pose problem, and answer to the questions are based on data propagated from the lab work and demonstrated concepts	Focused on both acquired and/ or alternatively constructed knowledge. Thus, any type assessment tools can be used, that can measure contents, process, and NOS and PS
	Scaffolding guided-discovery (SCGD)	Semi-structured, however guide lines, diagram, and laboratory set up given based on the request of students	Model-2	-Pose questions related to contents -PS, explicitly presented by lecture - NO, implicit activity-based approach In a form of pose question	Teacher pose problem, and answer to the questions are based on data propagated from the lab work, concepts injected /demonstrated concepts	Focused on both acquired and/ or alternatively constructed knowledge. Thus, any type assessment tools can be used, that can measure contents, process, and NOS and PS

Adapted from [2], [13], [56],[57]

Based on the gaps identified in many studies such as derivation and selection of dependent and covariates this study demonstrated an alternative approaches to derive dependent and covariates by combining two or three generic components (independent variables) in science education laboratory work. In this study, the independent variables are pedagogies, forms of laboratories, science contents, process skills, and nature of science. Note: in this study science contents, process skills, and nature of science being taught in laboratory used as one package. The following table-2 illustrates the combination effects of independent variables in terms of students' learning outcomes and motivation, and covariates in science laboratory studies.

Table-2 Dependent and covariate Variable derivation matrix

Independent variables	C= contents, NOS and PS in science	P=pedagogy	P x C
F=forms of Laboratory	F x C= PPS (practicing process skills)	F x P= PFLO (pedagogical and forms of laboratory orientation)	F x P x C= OLM (overall learning outcomes and motivation)
P= Pedagogy	P x C=MC (mastering contents)	-	-

Where, F, P, and C are independent variable. Whereas, PPS, PFLO, MC, and OLM are the combined effect of two or three independent/generic components. That may be used as dependent and /or covariates.

In above table-2 F refers to different forms/arrangement of science/physics laboratory to support learning (practicing PS). P refers to different pedagogies used to support learning in science/physics laboratory. In addition, C refers to contents, process skills, and nature of science being taught in science/physics laboratory. P x C, is the combination effect of pedagogy and contents being taught in science/physics laboratory. PPS, refers to the interaction effect of forms of laboratory(F) and contents(C) being taught in science such as develop skills to practice process skills in science to conduct experiments in different forms of laboratory about concepts in science/physics, and develop insight to conduct experiments in science. MC refers to the interaction effects of pedagogy(P) and contents(C) being taught in science laboratory work such as develop knowledge (mastering of contents) about facts, concepts, procedures, and NOS in science laboratory work, i.e it is more related with academic achievement. PFLO refers to the interaction effect of both pedagogy (P) and forms of laboratory (F) such as different perception/orientation about pedagogy and forms of laboratory, knowledge and skills to design laboratory for different pedagogical approaches (integration). OLM refers to the interaction effect of three independent variables (F, P, and C) such as develop well-substantiated knowledge about facts, concepts, process, and nature of science, i.e overall learning outcomes and motivation in science laboratory work[2].

In this study, FxPxC(OLM) selected as dependent variables. Because it is the complete combined effect of three main generic components. Whereas FxP, FxC, and PxC are selected as covariates. Because in each combination of the two, the dominant effect of one component missed. That means, when the researcher focused on either integration of forms of laboratory and pedagogy, forms of laboratory and contents being taught, and pedagogy and contents being taught in science laboratory, one of the components effect missed in each two pairs generic components. Note: in science education and/ or laboratory work, there are many other dependent and covariate variables [6],[8], [10], [14], [15], [16], [18], [58]., but in context of this study some selected variables mentioned both in dependent and covariates. According to the method used in this study, any researcher can derive and select the variables based on the context and objective of the study. Because, that was one of the gap identified in the area of study. Thus, this way of selection and derivation of variables in science/physics laboratory work makes this study different. Therefore, the findings of this study may explore the gaps in area of study and transform the existing science/physics laboratory reality in colleges of teachers' education. On the way, it used as evidence to shift teach-to-transmit habits in laboratory into balanced approach of student and teacher, and to shift acquired form of learning into both acquired and construct an alternative knowledge. To demonstrate these, the study selected four models of learning and implemented in physics laboratories of colleges of teachers education. Therefore, the followings are objectives of the study.

Objectives

The objectives of this study are to compare the impacts (pre-post test) of modified-guided-discovery methods and conventional method within a group in terms of dependent and covariate variables. In addition, measure the contributions of covariates on significant dependent variable/s in each group. Dependent variables are conceptual and procedural knowledge, views of nature of science and process skills, and motivation. Whereas, covariate variables are pedagogical and forms of laboratory orientation, practicing of process skills, and overall academic performance (CGPA).

Hypothesis

H_{01}: There is no significant mean score difference within groups' pre-post test in terms of conceptual and procedural knowledge, views of nature of science and process skills, and motivation.

H_{02}: There is no significant mean score difference within groups' pre-post test in terms of covariates of pedagogical and forms of laboratory orientation, practicing of process skills, and overall academic performance (CGPA).

H_{03}: There is no significant contribution of covariates on significant dependent variables in each group.

2. Methodology

2.1. Design of the Study

The background theories that support this study are social-constructivism and self-determination. Social-constructivism theory of learning used to guide classroom intervention, whereas, self-determination theory used to guide modification of guided-discovery method. According to social-constructive theory, knowledge constructed via social interaction. In this view, teacher and students considered as social group, and interact with each other to acquired and/ or construct an alternative knowledge in science/physics laboratory work. In addition, self-determination theory has significant contribution in different levels of guided discovery methods [47],[48]. The reason is that, in teaching-learning process students need proficiency, independency, and connection with teacher. Because, the teacher fills students gap of prior knowledge or forming initial schema, support development of emerging concepts, and manipulation skills about apparatus in science laboratory work[2]. Thus, this theory has significant contribution for implementation of different instructional methods, especially modified guided-discovery methods in science/physics laboratory work.

This study implement three-paired match modified guided discovery methods in comparison with conventional method. The study employed tandem design phase (III) with quasi-experimental approach. According to Campbell &Stanley [59], if there are two or three paired match groups, and quasi-experimental approach implemented within non-equivalent groups, tandem design with different phases suggested. The pair match groups in this study are similar in department (physics students), stay time in college (third year). In addition, they have learned the same courses at the same time. Moreover, the same assessment tools and mechanisms used. Furthermore, all groups learn science process skills explicitly, and NOS implicit in activity based approach. Their differences are in types of pedagogy, forms of laboratory, and model of knowledge construction.

Design of the study

Control group-0	NR→O→X_0→O
Treatment group -1	NR→O→X_1→O
Treatment group-2	NR→O→X_2→O
Treatment group-3	NR→O→X_3→O

Where, NR=non-random sampling, O=observation, X=treatment, and, 0,1,2,3 are pair match groups

2.2. Method of the study

This study employed comparative and association studies. Thus, quantitative methods of data collection and analysis used [60],[61]. To collect data about views of NOS and PS, motivation, pedagogical and forms of laboratory orientation, and practicing of process skills rated scale type used. Whereas, to collect data about conceptual and procedural knowledge multiple choice type test used. In addition, students overall academic performance (CGPA) gathered from registrar office of colleges.

2.3. Population and Samplings

There are five college of teachers' education in the target area of this study. Thus, multistage samplings method used to select study subjects. As the study employed quasi-experimental approach, first convenience-sampling used to select two most similar colleges in physics laboratory facility condition. The reason is to conduct experiments in similar way in all groups. By this, both Arbaminch and Hossana College of teacher education selected. Next to this, purposive sampling used to select most similar (paired match) groups that taking the same content in pervious time and in the entire semester of the study in two colleges. In addition, students' sufficient orientation about pedagogies and forms of laboratory used in college considered. By this, third year physics department students selected. In the selected two colleges, physics students took at least three laboratory courses and greater than eight physics content courses in the same sequence about electricity, magnetism, and electric circuit concepts. Finally, random sampling used to assign treatment and comparison group in two colleges. With this, one control and one treatment group (SSGD) assigned to Hossana college of teacher education, and two treatment group (SGD and SCGD) assigned to Arbaminch college of teacher education. Similarly, to assign each treatment groups within college random sampling used. Finally, the study comprehensively participate all students in natural class setting. The total numbers of students in the two colleges were 135. Out of these, the number of students participated both in pre and post testing were 112. Out of these, 24 students were in comparison group, 32 in SGD, 27 in SSGD, and 29 in SCGD implemented groups.

2.4. Data Gathering Procedures and Treatments

In conducting this study, different procedures and treatments employed.

Before intervention

Before intervention start, facility condition rechecked in two colleges in terms of equipments to conduct experiments in similar way about contents selected in the study. Then consent of agreement conducted with participant groups (instructors and laboratory technicians) and training given for those implement three modified guided-discovery methods. Before implementing study design, lesson plan (supportive material) and tools prepared and validated. In addition, pre-test conducted about all study variables, and explicit lesson given by the class teacher about PS for all groups.

During intervention

During intervention of study design, continuous formative feedback given for teachers and students in terms of distributing checklist about what practicing of PS and NOS learned per each experiment, and reporting formats. There is/are no any senior groups in college that taking or took the same course except the treatment group in the colleges. Thus, there is less uncontrolled group that makes contamination within college. To minimize within group contamination after conducting experiments in reporting of laboratory work, the first level data analysis and answers to some selected questions conducted during the experimentation time, and signed/marked by class teacher. In addition, each treatment group informed the content they will do in a class (after they came to laboratory). To minimize within group contamination, fixed grouping method used. One group contains 4-5 students. One experimental period is two to three hours. The total numbers of experiments conducted were seven. They are charging bodies, simple electric circuit, series and parallel circuit, Kirchhoff's 'rule, electromotive force and internal resistance, induced electromotive force, colour coding of resistance and verification by Ohms law. The laboratory work accomplished in 10 weeks from 16 weeks of academic calendar of the college.

After intervention

After implementing study design, post-tests conducted in all groups about all study variables. In addition, compensation sessions prepared for treatment groups. With this two to three, experiments conducted in natural laboratory set up in the remaining six weeks of academic year.

2.5. Instruments of Data Collection

After identify dependent and covariates by using method of deriving variables in science laboratory as mentioned in this study, tools used to measure each variables searched in literature and developed based objectives and context of laboratory work. According to this, tools used to measure conceptual and procedural knowledge test developed in context of laboratory work [10], [34]. They are objective in type (multiple choice). Independently, conceptual and procedural knowledge test are 10 in number total of 20 items administered. Both tests developed from the courses they took at the entire time of the study (year three semester-I course) that related to electricity, magnetism, charging and discharging of bodies, and simple circuit. Items used to measure views of nature of science and process skills is VNOS form-D, that is modified by Ling, et als [62]. They are 24 in number and likert scaled in type. Similarly, questions about motivation are adapted from [63],[64]. They are likert scale in type and eight in number. In addition, questions related to pedagogical and forms of laboratory orientation developed by researcher, they are rated scale in type and six in number. Furthermore, questions used to measure practicing of process skills are likert scale in type and 14 in number. They are basic and integrated process skills presented in literatures and in science curricula used in college [1], [65]. Hence, based on the curricula, researcher developed the questions in terms of objective and context of laboratory work. Finally, students overall academic performance (CGPA) collected from registrar office from two colleges.

2.7. Tool validation

To determine the reliability (internal consistency) of likert scaled questions Cronbach alpha used. To validate conceptual and procedural test Kuder-Richardson KR_{20} used. Even though conceptual and procedural knowledge testes used in physics laboratory not needs standardization, because they should be context based [10], [34], however, to the trustworthiness of the study, and to get problems on questions, it was piloted. Based on the findings some questions modified. All instruments piloted on third year physics students before a year this study conducted. The objective of validation of both adapted and new developed tools are to explore the nature of tools in context of study area. The pilot test conducted on 38 students. The detail presented below in table-3.

Table-3. Reliability test of tools

Type of Tools	No of items	Kuder-Richardson KR_{20}/Cronbach's Alpha		
		This work result	Previous result	Remark
Pedagogical & laboratory orientation	6	0.83	-	Researcher developed
Practicing of process skills	14	0.834	-	Researcher developed
Conceptual knowledge test	10	0.87	-	Researcher developed
Procedural knowledge test	10	0.79	-	Researcher developed
Motivation	8	0.764	0.78	Adapted/modified
Views of NOS and PS	24	0.78	0.67	Adapted &modified

Source: [2]. The reliability test indicated that, all the instruments in likert scaled are reliable and in usable range, because the Cronbach alpha value is $\alpha > 0.7$. In the same way content, face, and construct validity of the tools conducted by participating instructors in colleges of teacher education. The participated instructors are from different disciplines such as English language and physics teachers in the colleges. In addition, experts (Co-Authors) of this study had great contribution.

2.8. Statistical Analysis Techniques

In this study, descriptive and inferential statistics used to compare groups in terms of dependent variables. Paired sample t-test used to examine the impacts of each implemented pedagogies (modified guide-discovery and conventional) on dependent and covariate variables. In addition, multiple regressions used to identify the association of covariates and significant dependent variables in each group. SPSS Version 22 employed to do this.

The following is initial model represent the analysis of variables in this study.

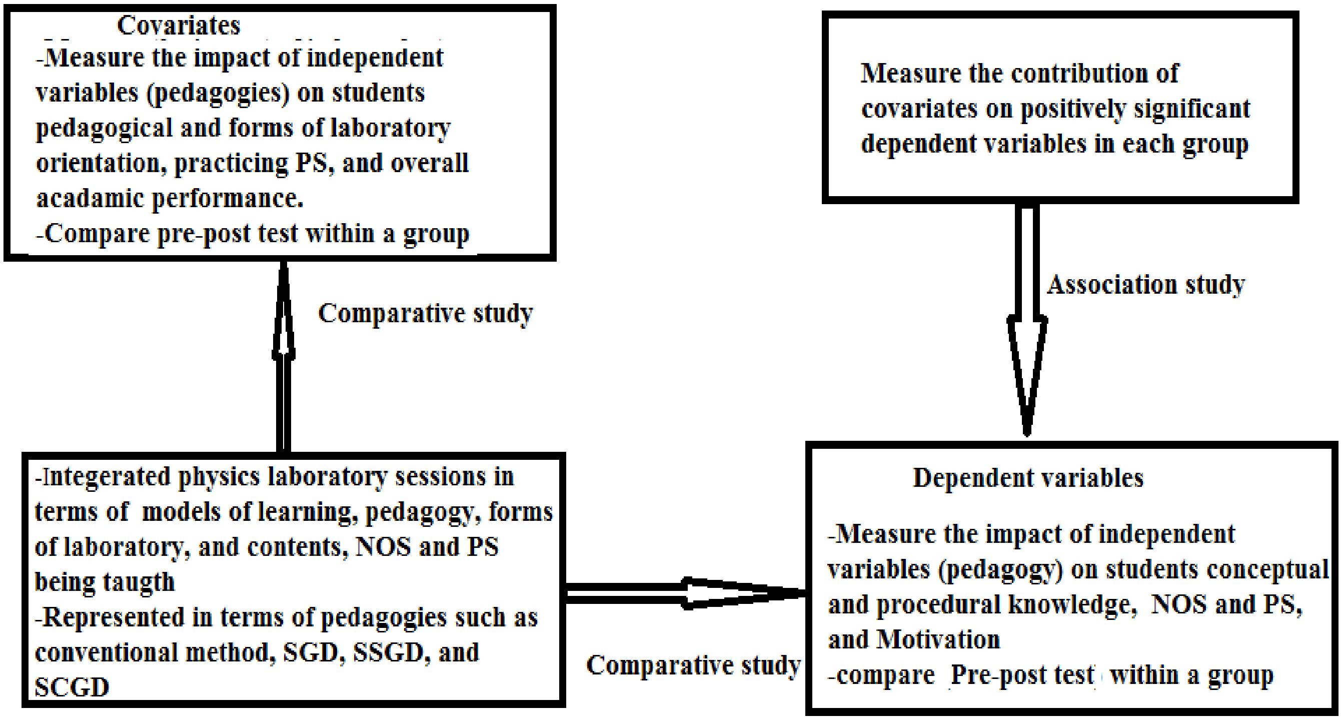

Fig-2. Initial model of analysis

3. Findings

3.1. Within group pre-post test comparison of dependent and covariates

In the following section, the null hypothesis H_{01} and H_{02} tested, i.e. the impacts of implemented pedagogy on dependent and covariate variable in each group. Paired sample t-test used.

Table.4. Descriptive Statistics of dependent variables.

Group	Pairs test of variables		N	Mean	SD	Std. Error Mean
	Pair 1	Conceptual post	24	3.6250	1.34528	.27460
		Conceptual pre	24	4.7917	1.28466	.26223
Control group	Pair 2	Procedural post	24	3.9167	1.13890	.23248
		Procedural pre	24	3.9167	1.50121	.30643
	Pair 3	Nos and PS post	24	54.6250	6.88926	1.40627
		NOS and PS pre	24	56.8750	8.10428	1.65428
	Pair 4	Motivation post	24	24.4583	3.27014	.66752
		Motivation pre	24	24.5000	2.84376	.58048

Structured (SGD)	Pair 1	Conceptual post	32	4.8438	1.90262	.33634
		Conceptual pre	32	4.7813	1.84451	.32607
	Pair 2	Procedural post	32	5.8125	2.02305	.35763
		Procedural pre	32	3.8438	1.88559	.33333
	Pair 3	Nos and PS post	32	55.6250	8.83450	1.56173
		NOS and PS pre	32	55.3750	6.02013	1.06422
	Pair 4	Motivation post	32	27.2500	2.47569	.43764
		Motivation pre	32	24.3438	3.40407	.60176
Semi-structured (SSGD)	Pair 1	Conceptual post	27	5.1481	1.56165	.30054
		Conceptual pre	27	4.0370	1.37229	.26410
	Pair 2	Procedural post	27	5.5185	1.60217	.30834
		Procedural pre	27	2.9630	1.53125	.29469
	Pair 3	Nos and PS post	27	56.3704	7.06099	1.35889
		NOS and PS pre	27	56.6667	6.29408	1.21130
	Pair 4	Motivation post	27	25.3704	3.54258	.68177
		Motivation pre	27	23.5185	3.51229	.67594
Scaffolding (SCGD)	Pair 1	Conceptual post	29	4.6207	2.14499	.39831
		Conceptual pre	29	4.5862	1.08619	.20170
	Pair 2	Procedural post	29	6.0690	1.62417	.30160
		Procedural pre	29	4.4138	1.40197	.26034
	Pair 3	Nos and PS post	29	56.5172	8.74488	1.62388
		NOS and PS pre	29	57.8621	6.65864	1.23648
	Pair 4	Motivation post	29	25.5172	3.13529	.58221
		Motivation pre	29	25.5172	2.83625	.52668

The data in table-4 indicates that, three treatment groups (modified guided-discovery methods) had better gain in all dependent variables compared to conventional method. For the reason that, in all variables the post test score is greater than pre test scores. However, in control group the post and pre test values are closer to each other.

Table.5. Paired sample test of dependent variables.

Group	Pairs of variables(post- pre)	Paired Differences Mean	SD	Std. Error	T	df	p (2-tailed)
Control	Conceptual post – conceptual pre	-1.16667	1.68540	.34403	-3.391	23	.003
	Procedural post – procedural pre	.00000	1.81779	.37105	.000	23	1.000
	Nos post – NOS pre	-2.25000	8.49680	1.73440	-1.297	23	.207
	Motivation post – motivation pre	-.04167	3.80479	.77665	-.054	23	.958
Structured (SGD)	Conceptual post – conceptual pre	.06250	2.71124	.47928	.130	31	.897
	Procedural post – procedural pre	1.96875	2.57136	.45456	4.331	31	.000
	Nos post – NOS pre	.25000	9.69203	1.71333	.146	31	.885
	Motivation post – motivation pre	2.90625	3.82993	.67704	4.293	31	.000
Semi-structured (SSGD)	Conceptual post – conceptual pre	1.11111	1.96769	.37868	2.934	26	.007
	Procedural post – procedural pre	2.55556	2.15430	.41460	6.164	26	.000
	Nos post – NOS pre	-.29630	8.63720	1.66223	-.178	26	.860
	Motivation post – motivation pre	1.85185	4.88879	.94085	1.968	26	.060
Scaffolding (SCGD)	Conceptual post – conceptual pre	.03448	2.07851	.38597	.089	28	.929
	Procedural post – procedural pre	1.65517	1.96897	.36563	4.527	28	.000
	NOS post – NOS pre	-1.34483	11.69028	2.17083	-.619	28	.541
	Motivation post – motivation pre	.00000	3.31662	.61588	.000	28	1.000

Paired sample t-test values of dependent variables indicates that, control group is significant in conceptual knowledge (p = .003), however the mean difference is negative, i.e post test score is less than pre test score.. SGD implemented group is significant in both procedural knowledge (p =.000), and motivation (p=0.000). In addition, SSGD implemented group is significant both in conceptual knowledge (p=0.007) and procedural knowledge (p=0.00). Finally, SCGD implemented group is significant only in procedural knowledge (p=0.00). The result indicated that, three phases of modified guided-discovery groups are commonly significant in conceptual knowledge test, and positive gain on conceptual knowledge test and motivation. Nevertheless, all methods had not significant positive impact on views of NOS and PS.

Table 4.15. Descriptive statistics of covariates

Group	Pairs of variables pre and post	N	Mean	SD	Std. Error
Control	Pedagogical orientation post	24	16.4583	3.51369	.71723
	Pedagogical orientation pre	24	16.0000	2.96355	.60493
	Practicing Process post	24	29.5417	6.95938	1.42058
	Practicing Process pre	24	25.8750	6.98640	1.42609
	Pervious academic Post GPA	24	2.7013	.53641	.10949
	Pervious academic pre CGPA	24	2.6442	.56995	.11634
Structured guided-discovery	Pedagogical orientation post	32	16.8125	4.13824	.73154
	Pedagogical orientation pre	32	16.2500	3.41722	.60409
	Practicing Process post	32	27.6250	6.96882	1.23193

	Practicing Process pre	32	24.5000	7.87810	1.39267
	Pervious academic Post GPA	32	2.6141	.52246	.09236
	Pervious academic CGPA	32	2.5847	.53804	.09511
Semi-structured guided-discovery	Pedagogical orientation post	27	16.1111	3.73480	.71876
	Pedagogical orientation pre	27	15.0000	3.10087	.59676
	Practicing Process post	27	28.5556	7.43347	1.43057
	Practicing Process pre	27	27.7037	6.44393	1.24013
	Pervious academic Post GPA	27	2.7407	.54593	.10506
	Pervious academic CGPA	27	2.6948	.57149	.10998
Scaffolding guided-discovery	Pedagogical orientation post	29	16.2759	3.84426	.71386
	Pedagogical orientation pre	29	15.4828	2.95950	.54956
	Practicing Process post	29	29.1724	6.23394	1.15761
	Practicing Process pre	29	25.0690	7.59196	1.40979
	Pervious academic Post GPA	29	2.5959	.46513	.08637
	Pervious academic CGPA	29	2.5703	.50245	.09330

From the table-6, all groups in all covariate variables had demonstrated positive gain. Because, three covariate variables post score are greater than pre score values. Hence, the implemented pedagogies had positive impacts on the covariates in each group.

Table.7.Paired sample test of covariates.

Group	Pair of variables post-pre	Paired Differences Mean	SD	t	Df	p (2-tailed)
Control	Pedagogical post – pedagogical pre	.45833	3.70639	.606	23	.551
	Process post – process pre	3.6666	5.36224	3.350	23	.003
	CGPA Post–CGPA pre	.05708	.19146	1.461	23	.158
SGD	Pedagogical post – pedagogical pre	.56250	4.47169	.712	31	.482
	Process post – process pre	3.1250	7.71572	2.291	31	.029
	CGPA Post –CGPA pre	.02937	.19532	.851	31	.401
SSGD	Pedagogical post – pedagogical pre	1.1111	4.65199	1.241	26	.226
	Process post – process pre	.85185	7.52280	.588	26	.561
	CGPA Post –CGPA pre	.04593	.08054	2.963	26	.006
SCGD	Pedagogical post – pedagogical pre	.79310	4.55427	.938	28	.356
	Process post – process pre	4.1034	6.83136	3.235	28	.003
	CGPA Post–CGPA pre	.02552	.07119	1.930	28	.064

Table-7 describes paired sample test of impacts of modified guided-discovery methods and conventional method on covariates. The results indicate that, there is significant change on practicing of process skills in conventional, SGD, and SCGD implemented groups. SSGD method implemented group is significant in overall academic performance. Though there is positive gain, but all groups are not significant in pedagogical and forms of laboratory orientation and academic performance. This finding indicates that, covariates used in the study are affected by implemented pedagogies in each group. Therefore, the study assumes, there is direct or indirect contributions of these variables on significant dependent variables in each group. For this reason, in this study their (covariates) contribution on each groups significant variables analyzed to identify to what extent they contribute to significant dependent variables in each group. Thus, the following section analyzes the contribution of covariates in each group significant dependent variables.

3.2. The Contribution of covariates on significant dependent variables in each group

In this section, the third hypothesis tested. The reason to this test is based on the empirical observation that, the selected covariate variables are positively affected by implemented pedagogies in each group. Thus, the following assumption emerged such as, in addition to the implemented pedagogies, there is contribution of covariates on positively significant dependent variables in each group. As we saw in table-5, control group is significant in conceptual knowledge; however, the mean difference of post-pre test is negative, i.e not positive gain. SGD implemented group is positively significant in both procedural knowledge and motivation. In addition, SSGD implemented group is positively significant both in conceptual knowledge and procedural knowledge, and SCGD implemented group is positively significant only in procedural knowledge. Thus, the following section analyzes the contribution of covariates on each group positively significant dependent variable/s.

Table.8. Regression table for SGD implemented group for procedural Knowledge

Analysis of Variances					
Model	Sum of Squares	Df	Mean Square	F	P
Regression	26.074	3	8.691	2.414	.088
Residual	100.801	28	3.600		
Total	126.875	31			

Variable in Equation							
Variable	Mean	B	St.error	Beta	T	P	r
Constant		-1.089	2.911		-.374	.711	
Procedural knowledge	5.8125				.816	.421	1.000
Pedagogical orientation	16.8125	.077	.094	.157	.867	.393	.015
Practicing PS	27.6250	.045	.051	.154	2.282	.030	.237

CGPA	2.6141	1.674	.734	.432	-.374	.711	.386

The impact of covariates (R^2) on procedural knowledge in SGD method implemented group is R^2=0.206, and the adjusted R square is -0.120.

Procedural knowledge has better correlation with overall academic performance in structured guided-discovery implemented group. However, it has small correlation with pedagogical and forms of laboratory orientation. The small correlation implies that, student s' interest/selection of pedagogy and forms of laboratory score is less correlate with their procedural knowledge test score. In this group procedural knowledge has relatively better correlation with overall academic performance of students. That means students CGPA score has direct relation with their procedural knowledge test score. The impact factor of covariates on procedural knowledge analyzed for SGD implemented group is:

$$R^2 x100\% = \beta_{Ped}*r_{ped} + \beta_{PPS}* r_{PPs} + \beta_{CGPA}*r_{CGPA}) \times 100\%$$

$$R^2 x100\%=(0.157 *0.015+ 0.154 *0.237+0.432*0.386)x100\%$$

$$R^2 x100\%=0 .206x100\%= (0.002355 + 0.036498 + 0.166752) 100\%$$

$$20.6\%=0.2355 \%+3.6498 \%+ 16.6752\%$$

In SGD implemented group, the contributions of covariates on procedural knowledge is not statistically significant $F (3, 28) =2.414$, $p>.05$; however the overall contribution is 20.6%. Out of this, the contribution of academic performance is 16.6752%, and practicing of process skills is 3.6498%. The adjust R square value was -0.120. This indicates 12% of the variance in procedural knowledge explained by covariates. According to Cohen [66], it is in a small range.

According to Cohen[66] the range of impacts are if adjusted R^2=0.14 represents a small effect, R^2=0.36 represents a medium effect, R^2 =0.51, is large effect, and R^2 =0.71+ represents a much large effect.

The identified equation to this relationship was procedural knowledge = -1.089+(0.077*pedagogical orientation)+(0.045*practicing of process skills)+(1.674*CGPA).

$$5.8125=-1.089 +0.077* 16.8125+ 0.045*27.6250+ 1.674*2.6141$$

$$5.8125= -1.089 + 1.2945625+ 1.243125 + 4.3760034=5.8246909$$

From the equation, we can see that, overall academic performance (CGPA) had relatively greater positive impact on the mean score of procedural knowledge. Pedagogical and forms of laboratory orientation and practicing process skills had small positive impact on procedural knowledge. This implies all covariates had positive impacts on the procedural knowledge test score in SGD implemented group. However, the effect is small.

Table.9. Regression table for SGD implemented group for motivation.

Analysis of Variance

Model	Sum of Squares	Df	Mean Square	F	P
Regression	13.731	3	4.577	.727	.544
Residual	176.269	28	6.295		
Total	190.000	31			

Variable in Equation

Variable	Mean	B	St.error	Beta	T	p	r

Constant		28.223	3.850		7.331	.000	
Motivation	27.2500						1.000
Pedagogical orientation	16.8125	.083	.125	.138	.662	.514	.209
Practicing PS	27.6250	-.004	.068	-.011	-.059	.953	-.002
GPA	2.6141	-.860	.970	-.181	-.886	.383	-.239

The impact of covariates (R^2) on motivation in SGD method implemented group is R^2=0.072, and the adjusted R square is -0.027.

Motivation had relatively better correlation with pedagogical and forms of laboratory orientation than with other covariates. It has negative correlation with both practicing PS and overall academic performance. The negative correlation implies that, students practicing of process skills and overall academic performance score are opposite to their motivation score. The impact factor of covariates on motivation analyzed as:

R^2x100%= β_{Ped}*r_{ped} + β_{PPS}* r_{PPs} + β_{CGPA}*r_{CGPA})×100%

R^2x100%=(.138*0.209-.011*-.002 -.181*-.239)100%

0 .072x100%= (0.028842+0.000022+ 0.043259) 100%

7.2%=2.8842% +0.0022%+ 4.3259%=7.2123%

For SGD implemented group, the contribution of covariates on motivation is not significant, F (3, 28) = .727, p = .544, and the overall effect on motivation is 7.2%. This sis small effect. Out of this, the contribution of overall academic performance is 4.3259%, pedagogical and a form of laboratory orientation is 2.8842%. The adjust R^2 value was 0.027. This indicates that 2.7% of the variance in motivation explained by pedagogical and forms of laboratory orientation, practicing of process skills, and overall academic performance. According to Cohen[66], this is in very small range.

Table.10. Regression table for SSGD implemented group for Conceptual knowledge.

Analysis of variance

Model	Sum of Squares	Df	Mean Square	F	P
Regression	17.555	3	5.852	2.935	.055
Residual	45.852	23	1.994		
Total	63.407	26			

Variable in Equation

Variable	Mean	B	St.error	Beta	T	p	r
Constant		.879	2.150		.409	.686	
Conceptual knowledge	5.1481						1.000
Pedagogical orientation	16.1111	-.027	.078	-.065	-.347	.732	-.036

Practicing PS	28.5556	.017	.040	.081	.426	.674	-.057
CGPA	2.7407	1.538	.522	.538	2.948	.007	.519

The impact of covariates (R^2) on conceptual knowledge in SSGD method implemented group is R^2=0.277, and the adjusted R square is -0.183.

Conceptual knowledge has better correlation with overall academic performance (CGPA) compare to other covariate variables. It has negative correlation with pedagogical and forms of laboratory orientation and practicing of process skills. The negative correlation implies that, students' interest/selection of pedagogy and forms of laboratory and practicing PS score are opposite to their conceptual knowledge test score. The impact factor of each covariate on conceptual knowledge analyzed as:

$$R^2x100\% = \beta_{Ped}*r_{ped} + \beta_{PPS}*r_{PPs} + \beta_{CGPA}*r_{CGPA}) \times 100\%$$

$$R^2x100\%=(-0.065* -0.036+ 0.081* -0.057+0.538*0.519)100\%$$

$$R^2x100\%=0 .277x100\%= (0.00234-0.004617+ 0.279222)\ 100\%$$

$$27.7\%=0.234\% -0.4617\%+ 27.9222\%=27.6945\%$$

For SSGD implemented group, the contribution of covariates on conceptual knowledge is significant, $F (3, 23) = 3.301$, $p = .05$, and the overall effect is 27.7%. Out of this, the contribution of overall academic performance is 27.9222%, pedagogical and a form of laboratory orientation is 0.234%, and practicing process skills is -0.4617%. The adjust R^2 value was -0.1830. This indicates that 18.3% of the variance in conceptual knowledge explained by covariates used in the study. According to Cohen, this is in small range. The identified equation to understand this relationship was conceptual knowledge =0.879+ (-.027*pedagogical orientation) + (.017 * practicing level of process skills+ (1.538*overall academic performance (CGPA)).

$$Y=0.879+ (-.027*16.111) + (.017 *25.5556 + (1.538*2.7407).$$

$$5.1481=0.879+ (-0.434997+0.4344452+4.2151966) =5.0936448$$

From the equation, overall academic performance of the group had positive impact on the mean score of conceptual knowledge. Pedagogical and forms of laboratory orientation had negative impact, and practicing process skills had positive, but small impact on mean score of conceptual knowledge. This implies that, in SSGD implemented group students' academic performance had greater impact on their conceptual knowledge test score than other covariate variables.

Table.11. Regression table for SSGD implemented group for Conceptual knowledge.

Analysis of variance

Model	Sum of Squares	df	Mean Square	F	p
Regression	12.406	3	4.135	1.751	.185
Residual	54.335	23	2.362		
Total	66.741	26			

Variable in Equation

Variable	Mean	B	St.error	Beta	T	P	r
Constant		2.555	2.341		1.092	.286	

Procedural knowledge	5.5185						1.000
Pedagogical orientation	16.1111	-.024	.085	-.056	-.282	.780	-.055
Practicing PS	28.5556	-.002	.044	-.011	-.056	.956	-.122
CGPA	2.7407	1.247	.568	.425	2.195	.039	.427

The impact of covariates (R^2) on procedural knowledge in SSGD method implemented group is R^2=0.186, and the adjusted R square is -0.080.

Procedural knowledge has better correlation with overall academic performance than the other covariate variables. It has negative correlation with pedagogical and forms of laboratory orientation and practicing of PS. The negative correlation implies students' selection of pedagogy and forms of laboratory, and practicing of process skill scores are opposite to procedural knowledge test score. The impact factor of covariates on procedural knowledge analyzed as:

$$R^2x100\% = \beta_{Ped}*r_{ped} + \beta_{PPS}*r_{PPs} + \beta_{CGPA}*r_{CGPA}) \times 100\%$$

$$=(-.056*-.055 + -.011* -.122+ .425*0 .427)$$

$$R^2x100\%=0 .186x100\%= (0.00308+0.001342+ 0.181475) 100\%$$

$$18.6\%=0.308\% +0.1342\%+ 18.1475\%=18.5897\%.$$

In SSGD implemented group, the contribution of covariates on mean score of procedural knowledge is not significant, F (3, 23) = 1.751, p = .185. However, the overall effect of covariates on procedural knowledge is 18.6%. Out of this, the contribution of pedagogical and forms of laboratory orientation is 0.308%, practicing of process skills is 0.1342% and overall academic performance is 18.1475%. Out of three covariates, overall academic performance had greater effect than the other two variables on procedural knowledge. The adjusted R^2 value was 0.08. This indicates that 8.0% of the variance in procedural knowledge explained by covariates. This is small effect. The identified equation to relationship was procedural knowledge =2.555+ (-.024*pedagogical orientation) + (-.002*practicing process skills) + (1.247*overall academic performance).

$$Y=2.555+ (-.024*16.1111) + (-.002*28.5556) + (1.248*2.7407)$$

$$5.5185=2.555-0.386664-0.0571112+ 3.4203936=5.5316184$$

From the equation, overall academic performance of the group had greater positive impact on procedural knowledge. Pedagogical and forms of laboratory orientation and practicing process skills had negative impact on procedural knowledge in SSGD implemented group. That may implies that, the change of traditional method approach had impact on their pedagogical and forms of laboratory orientation, and practicing process skills.

Table.12. Regression table for SCGD implemented group for procedural knowledge.

Analysis of variance							
Model	Sum of Squares	df	Mean Square	F	P		
Regression	16.585	3	5.528	2.413	.090		
Residual	57.277	25	2.291				
Total	73.862	28					
Variable in Equation							
Variable	Mean	B	St.error	Beta	T	P	r

Constant		.792	2.095		.378	.709	
Procedural knowledge	6.0690						1.000
Pedagogical orientation	16.2759	.089	.081	.210	1.097	.283	.237
Practicing PS	29.1724	.005	.051	.019	.096	.924	.172
CGPA	2.5959	1.423	.625	.408	2.277	.032	.421

The impact of covariates (R^2) on procedural knowledge in SCGD method implemented group is R^2=0.225, and the adjusted R square is -0.131.

Procedural knowledge has better correlation with overall academic performance (CGPA) than with other covariate variables. The impact of each covariate on procedural knowledge analyzed as:

$$R^2 x100\% = \beta_{Ped} * r_{ped} + \beta_{PPS} * r_{PPs} + \beta_{CGPA} * r_{CGPA}) \times 100\%$$

$$R^2 x100\% = (0.210 * 0.237 + .019 * 0.172 + .408 * 0 .421) 100\%$$

$$0 .225x100\% = (0.04977 + 0.003268 + 0.171768) 100\%$$

$$22.5\% = 8.841 \% + 0.3268\% + 17.1768\% = 22.4806\%$$

In SCGD implemented group, the contribution of covariates on mean score of procedural knowledge is not significant, F (3, 25) = 2.413, p =0.09; however the overall effect is 22.5%. Out of this, the contribution of students' academic performance is 17.1768%, and the others are small. The adjusted R^2 value was 0.131. This indicates that 13.1% of the variance in procedural knowledge explained by covariates of the study. This is in small range. The identified equation was procedural knowledge=Y =0.792+(.089*pedagogical orientation)+(0.005*practicing level of process skills)+(1.423*overall academic performance).

$$6.0690 = 0.792 + (.089 * 16.2759) + (0.005 * 29.1724) + (1.423 * 2.5959$$

$$6.0690 = 0.792 + 1.4485551 + 0.145862 + 3.6939657 = 6.0803828.$$

From the equation, overall academic performance had relatively greater positive contribution on procedural knowledge. Next to it, pedagogical and forms of laboratory orientation had better positive impact. This may implies that, the change of traditional method in this group had positive impact.

Generally, the contribution of covariates analysis on each group significant dependent variable/s indicated that, there is effect of covariates on significant dependent variables, however the effect is small. The study indicates that, in addition to implemented pedagogies (modified guided-discovery) in each group, there is/are different types and levels of contribution of covariates on significant dependent variables in each group.

4. Discussion

The study implemented three alternative approaches of modified guided-discovery methods and conventional method in physics laboratories of college of teachers' education. Tandem design phase III with quasi-experimental approach implemented. The study employed both comparative and association studies. The results from within group comparison test (H_{01} test) of dependent variables indicated that, SGD implemented group is significant in procedural knowledge and motivation. In the same way SSGD implemented group is significant both in conceptual and procedural knowledge, and SCGD implemented group is significant only in procedural knowledge. Control group is not positively significant in all dependent variables. In addition, all groups are not significant in views of NOS and PS. In other way, all modified guided-discovery implemented groups are commonly significant in procedural knowledge.

Since implicit activity-based approach (answer questions related to NOS and PS based on the data gathered in physics laboratory work) and modified guided-discovery methods are new insight in science/physics laboratory work, hence, there is no directly agreeing or opposing result observed in literature. However, Baloy, et als [6] and Clough [56] used explicit reflective question during intervention about NOS and PS, and using guided-discovery (inquiry) as single phase of constructive approach opposes this study findings. This study finding indicated that, in physics contents related to electricity, magnetism, electric charge, and simple circuit, and the study design such as alternative integration of generic components represented in terms of pedagogy had not significant impact on students' views of NOS and PS. This revealed that, there are limitations in the material and curricula under use in college of teacher education in terms of integrating NOS and PS. The implications of this study finding is that, it requires educating pre-service teachers' about views of NOS and PS in a way different from the current college curricula or modify study design to bear the desired changes. Thus, may college curricula suggested to incorporate independent course related to history and philosophy of science for physics department students. In addition to this, may intensively implement this study design or modifying the study design improve students views' of NOS and PS, i.e may it is possible to use explicit approach of NOS and PS with constant model of learning, and integration of pedagogy and forms of laboratory used in this study.

The result of H_{02} test (the impacts of implemented pedagogies on covariates) indicate that, there is significant positive gain by conventional method implemented group, SGD implemented group, and SCGD implemented group in practicing of process skills. Though there is positive gain on pedagogical and forms of laboratory orientation in all groups but no statistically significant change achieved. In addition, in terms of academic performance (CGPA) except on SSGD implemented group other groups are not significant. This finding indicates that, covariates used in this study are affected by implemented pedagogies such as three alternative approaches of modified guided-discovery methods and conventional method. There is/are no directly related study identified that measure the impacts of pedagogies on covariate variables used in this study such as pedagogical and forms of laboratory orientation, practicing PS, and overall students' academic performance and compare their difference due to intervention of different pedagogies. However, this study indicated that, these (covariate) variables are positively affected by pedagogies used in science/physics laboratory work.

From the effect analysis of covariates (H_{03} test) on significant dependent variable/s in each group indicates that, the contribution of covariates on procedural knowledge in SGD implemented group is 20.6 % and on motivation in this group is 7.2 %. In the same way, the contribution of covariates in SSGD implement group on procedural knowledge is 22.7 %, and in this group on conceptual knowledge is by 18.6 %. Finally, the contributions of covariates in SCGD implemented group on procedural knowledge is 22.5 %. This implies that, in addition to; implemented study design (pedagogies) in each group, there is contribution of covariates on each group significant dependent variable/s. However, in terms to adjusted R^2, all covariates effect on significant dependent variable/s in each group is in small range. This type of analysis less appeared in science/physics education laboratory work literature; however, the study findings by Fikret & Eryilmaz [67] and Ryan & Guido [68] indicated that, orientation or selection of pedagogy and forms of laboratory have direct impacts on students' academic achievement and motivation.

Generally this study finding indicated that, using an alternative model of learning that guides selection and integration of generic components in physics laboratory session and implementing alternative approaches of modified guided-discovery methods had positive impact on students learning outcomes and motivation. In addition, this study indicated that, there is contribution of covariates (that obtained due to combination of two generic components effect see table-1) on significant dependent variables in each modified guided-discovery methods implemented group. The type and level of contribution of each covariate in each model of learning or pedagogy implemented group is different (unique). As evidence of this, colleges of teachers' education laboratory curricula suggested to appropriately integrate and implement generic components in science/physics laboratory. In addition, use model of learning that guides selection and integration of generic components in each science/physics laboratory lessons. Moreover, using derivation and selection criteria of dependent and covariates helps identify the types and nature of variables in science laboratory works. That directs to effectively measure the effect of independent variables (generic components) on the dependent and measure the contribution of covariates on dependent variables.

5. Conclusion, Educational implications, and Limitations

The study revealed that, the curricula under use in physics laboratory at colleges of teachers' education have limitations in integrating concepts, NOS and PS, pedagogies, and forms of laboratory. In addition, there are less using model of learning that guides selection and integration of generic components in science/physics laboratory. The study also revealed gaps in literatures such as less clear direction about integrations of pedagogy and forms of laboratory, less even no model of learning that guides selection and integration of generic components in science/physics laboratory. Moreover, there are less even no clear criteria used to derive and select variables (dependent and covariates) in different studies in science/physics laboratory work.

To fill these gaps, this study developed an alternative model of learning (acquired and/ or constructed) due to integration of pedagogy and forms of laboratory and that guides selection and integration generic components in science/physics laboratory work. Based on the models, pedagogies used in science/physics laboratory modified, especially guided-discovery levelled into three alternative approaches such as SGD, SSGD, and SCGD. Then they study aligned all components such as model of learning, forms of laboratory, pedagogies, and contents and NOS and PS being taught in physics laboratory sessions. In addition, this study proposed an alternative method to derive and select dependent and covariates from generic components (independent variables) of laboratory sessions. Finally, this study selected four models of learning and implemented on physics laboratories of college of teachers' education in contents related to electricity, magnetism, and electric circuit.

The findings after intervention revealed that, three alternative approaches of guided-discovery had significant impact on procedural knowledge, and positive impact on students' conceptual knowledge, and motivation. In addition, conventional and three alternative approaches of guided-discovery methods had positive impact on covariates (pedagogical and forms of laboratory orientation, practicing of process skills, and overall academic performance of students). In contrary to this, all implemented model of learning and integration of NOS and PS had not significant impact on students views of NOS and PS. The study conducted to identify the contribution of covariates in each group significant dependent variables indicated that, there are different types and levels of association (contribution) identified among dependent variables and covariate variables in each group. This implies that, in addition to independent(pedagogies), there is effect of covariates (interaction effect of two independent variables) on dependent variables(see table-1).

The implication of this study finding for science/physics laboratory works in terms of pedagogies is that, using alternative approaches of modified guided-discovery methods in physics laboratory had better positive impact on students' learning outcome and motivation. However, to enhance pre-service physics teachers' views of NOS and PS modification of college physics laboratory curricula and /or increasing the application of this study design suggested. In addition, this study is believed to fill up gaps in such a ways that, it introduced new trend in using model of learning that guides selection and integration of generic components in science/physics laboratory. Moreover, it introduces an alternative method to derive dependent and covariates from generic components of science/physics laboratory lessons. In studies about relationship of variables, mathematical operation gives a number that gives a clue about the relationship of variables; however the logic (experience) determined the further analysis. Thus, the concepts used in this study to derive and select the variables had contribution when conducting studies in science/physics laboratory. Thus, generally this study helps teacher or researcher to develop lessons that fit for models of learning, pedagogies and forms of laboratory. In addition, to appropriately derive and select the variables to be studied in science/physics laboratories.

The limitations of this study are, though the assessment methods in science laboratory are the generic components, however this study not focused on the assessment methods used in different pedagogy implemented groups. Researchers of this study believed that, different models used in science/laboratory needs different assessment methods that best fit for the models. However, due to objective type tests and structured forms of tools can alternatively used in any method, this study controlled assessment methods. Hence, this study used the same assessment tool (objective type for conceptual and procedural knowledge, and rated scale for the rest all dependent and covariates). In addition, qualitative data such as students' laboratory work report, and reflections on questions related to nature of science that incorporated in laboratory report (implicit activity-based approach) are not included in this study. Though practical skill test helps detail understand the effects each pedagogies, however it not conducted in this study. Thus, for further research these all limitations are workable dimensions by using this study design.

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