Practical work design based on Science, Technology, Engineering, Mathematics (STEM) on manufacture of liquid sugar from cassava peel waste (*Manihot esculenta*) to improve student creativity

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Abstract. The aim of this study is to create a practical work design based on science, technology, engineering and mathematics (STEM) on the manufacture of liquid sugar from cassava husks (*Manihot esculenta*) to improve the creative abilities of students. To achieve this, the question that arises in this study is "How can the characteristics of developing practical design based on science, technology, engineering and mathematics improve students' creativity?" The researcher used Design-Based Research (DBR) method consisting of 4 phases: Problem identification and analysis, Designing a solution, Repeated cycles in testing and refining designs and Reflection to produce the principles of design and implementation. The Participants in this study were senior high school students, chemistry teacher and 3 observers who understood the STEM approach. Data was collected by interviewing, testing and observing the activities students. The results showed that student creativity increased through STEM-based practice.

1. Introduction
Today's world development is progressing and developing, according to Harry industrial development in the world has reached the wave of industrial revolution 4.0, characterized by the presence of new technologies that fuse the physical, digital, and biological world, allowing for increased productivity, quality, and efficiency, which enables industrial products to be more globally competitive which causes social and environmental impacts such as information overload, unemployment as a result of insufficient knowledge and skills, socio-economic inequalities due to capital-intensive technology, and threats to environmental sustainability as a result of resource exploitation natural [1].

The paradigm of education which is generally used conventionally in schools now must be changed in order to answer the challenges of industrial development, namely students must have 21st-century skills namely 4C scientific literacy and skills which include; Communication, Collaboration, Critical thinking, and problem-solving, Creativity and innovation. The focus of this 4C skill is expected to help students to be able to use their abilities as a result of the learning process so that it is useful in solving problems and can compete in real life [2]. However, the fact is that students in Indonesia still have low ability to think in solving problems, especially in the field of science. The results of research conducted by PISA related to science literacy of Indonesian students from 2000 to 2015, showed that the average score of Indonesian scientific literacy was below the international average (<500). The low score of
Indonesian students' literacy science, one of which is caused by still adhering to the principle of memorization without being able to associate it with problems in everyday life, so students do not have the skills to become creative thinkers in solving problems. Therefore, students' creative thinking skills are important in learning activities [3].

Creativity possessed by students is closely related to thinking skills in solving problems. Current life demands, in other occupations and professions, require skills such as reasoning, creative thinking, making decisions and solving problems [4]. According to Boesdorfer and Livermore, creativity as a high student motivation has a positive influence on learning and learning outcomes [5]. How teachers motivate students, so that learning barriers can be reduced, teachers must try to make innovations in designing learning that makes students active in building their knowledge. Students build their knowledge or understanding, on the basis of interactions between the knowledge and views they have and the information they face and actively participate in the meaningful construction process, or in other words, students must be active in learning (student center). According to Demircioglu and Cagatay, Practicum activities in the laboratory can make students more active in their learning than in the classroom [6].

Therefore, students must be invited to be active and participate as a scientist in learning activities, by conducting practical activities as learning strategies. One learning strategy that can be used to train creativity is the learning approach of Science, Technology, Engineering, and Mathematics (STEM), according to Becker and Park, STEM is an important issue in education today [7]. STEM learning is an integration of learning science, technology, engineering, and mathematics that is suggested to help the success of 21st century skills [8]. Ching-san Iai states that STEM can develop when it is associated with the environment so that learning that presents the real world experienced by students in everyday life is realized. This means that through the STEM approach students are not just memorizing concepts, but rather how students understand [9] and understand scientific concepts and their relationships in daily life [10].

According to Quang et al in Lestari states that learning using the Science Technology Engineering Mathematics (STEM) the approach can provide students with learning experiences, active learning and contextual meaning. Meanwhile, according to Becker and Park in Lestari, the approach of Science Technology Engineering Mathematics (STEM) has a positive influence on student learning, and the application of Science Technology Engineering Mathematics (STEM) in learning can encourage students' creativity to design, develop and use technology, sharpen cognitively, manipulative and effective, and apply knowledge in their lives. Therefore, the application of STEM is considered appropriate for use in science learning. STEM-based learning can train students to apply their knowledge to create designs as a form of solution to problems related to the environment by utilizing technology [11].

The problems solving that exist in the surrounding environment is always related to handling waste that is in the daily lives of students. Green chemistry is one of the right approaches to training chemical students in preventing pollution and concern for waste. Hence various approaches have been used to prevent pollution and concern for waste in the context of education [12]. The expectations of the use of local waste in learning with topics that are appropriate and relevant to their lives will give rise to concern for the environment, one of which is the use of cassava peel waste, hence the researcher conducts research on The Development Practical Work Design Based on Science, Technology, Engineering, Mathematics (STEM) On Manufacture Of Liquid Sugar From Cassava Peel Waste (Manihot esculenta) To Improve Student Creativity.

2. Method

The method used in this study is a design-based research method (DBR), according to Collins et al [13]. Design-based Research is known as a design experiment that aims to overcome some Central needs and problems for learning studies These include the following: (1) The need to answer theoretical questions about the nature of learning in context, (2) The need for approaches to study learning phenomena in real-
world situations rather than in laboratories, (3) Need to go beyond steps narrow learning steps, (4) The need to obtain research findings from formative evaluations [13].

Method of Design-Based Research (DBR), this method is one of the methods of development. As stated by van den Akker states that "the term design research is included in developmental research, because it is related to the development of learning materials and materials [14]. Definition of Design-Based Research (DBR) according to Plomp design research is: design research is a systematic study of designing, developing and evaluating educational interventions (such as programs, strategies, and learning materials, products and systems) as solutions to solving complex problems in educational practice, which also aim to advance our knowledge of the characteristics of these interventions as well as the design and development processes (such as learning processes, learning environments and the like) with the aim of developing or validating theories [15].

The initial design of design-based research in this study consists of stages as follow:

![Diagram of Design-Based Research Process](image)

**Figure 1.** The initial design of design-based research in this study.

Plomp in Clark explains that Design-Based Research is a systematic education and instructional design process in which the process of analysis, design, evaluation, and revision activities can get satisfactory results. This method fits in the research that will be investigated because the results of this study are a practical design to increase creativity in students, this method can solve individual problems and involve many people, so that there is no need to use a lot of research using DBR research subject [16].

The research subjects in this study were senior high school students who were active in Kelompok Ilmiah Remaja (KIR) activities, as many as 20 students who attended SMAN 4 Garut. The instruments used in this design based research are as follows: Guidelines for interviews, in the form of questions that must be answered by respondents' questionnaires for teachers and students, Lembar Kerja Siswa (LKS) based on STEM, Rencana Pelaksanaan Pembelajaran (RPP), which researchers make will be adjusted to the 2013 curriculum, creativity questionnaire and guideline or rubric judgment.

3. **Result and discussion**

3.1. *The use of practical activities and practical instruments to assess the attitude of creativity in this learning*

From the results of interviews conducted to four chemistry teachers who used the 2013 curriculum can be concluded that teachers still cannot utilize practical activities as an alternative to some learning, teachers understand the importance of practical activities and laboratory use in learning activities, but due to lack of facilities adequate and curriculum demands that make teachers feel pressured so that they
are more concerned with classroom learning activities. And for the teacher who conducts practical activities in evaluating creativity, the teacher is still experiencing difficulties, especially in the process of evaluating and making assessment instruments. In evaluating creativity, teachers are generally still directly assessing the attitude of creativity without using a rubric instrument so that the assessment process is more subjective. Teachers expect guidance on evaluating creativity that can facilitate teachers in objectively evaluating creativity.

Based on the results of the literature study, it can be concluded that schools using the 2013 curriculum are on Macromolecular material, especially carbohydrates, competency KD 4.11 which requires students to be able to reason the making of macromolecules, in accordance with the curriculum competencies. From macromolecules, in the book, there are more activities to detect the presence of these macromolecular compounds. And based on the results of interviewing learning activities on the concept of macromolecules, especially carbohydrates, the teacher assigns students to learn independently from the book, due to time constraints, so learning in the concept of carbohydrates is poorly understood by students.

3.2. **Practical design instruments based on Science, Technology, Engineering and Mathematics (STEM)**

The research instruments after validating by several validators consisting of 3 expert lecturers and 4 chemistry teachers, experienced several revisions to aspects of science, because in the science aspect was not seen like carbohydrate molecular formula, reaction when undergoing hydrolysis and formation of liquid sugar, in addition to the technological aspect, it has not been seen the use of technology in learning activities, and several instruments not yet seen the purpose of skills the 21st-century (4C). Therefore, the researcher then corrected some instruments, especially in the RPP and LKS and the student creativity questionnaire, to fit the objectives and approaches applied, namely STEM and creativity.

3.3. **Implementation of questionnaire on creativity in practicum design for making liquid sugar**

At this stage, the researcher tests the product against the individual creativity assessment rubric. The first trial was conducted by 20 observers who conducted STEM-based practical activities, namely KIR students. Based on the first trial on the rubric of the assessment of individual scientific attitudes, it can be seen that there are 8 criteria which the percentage score given by the observer is greater than 75% so that it is declared feasible to use without revisions namely rubrics 1, 2, 4, 5, 6, 8, 9 and 10. The criteria that must be revised are 2 rubrics namely rubric 3 and 7. Based on expert agreement and the results of the observer rubric 3 and 7 must be revised.

4. **Conclusion**

The researcher concludes that students’ activities in making products in STEM-based practical activities on making liquid sugar teach students how to solve problems in the utilization of cassava peel waste, in addition students understand the application of science, technology, engineering, and mathematics in practical activities. The application of STEM in practical design enriches the ability of students to apply several disciplines, it answers the challenges of 21st-century capabilities, students are taught to think critically, communicate, collaborate and actively make liquid sugar from cassava peel waste in this case creating new innovations (creative). And the results of teacher and student interviews, STEM-based practicum design became alternative learning in the laboratory that can improve student creativity and be a solution for teachers to teach chemical concepts especially in learning macromolecules especially the concept of carbohydrates.

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