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# Physics Teachers' Implementation of Competence-Based Curriculum through the use of Inquiry-Based Teaching and Learning: A Case of Lower Secondary Schools in Gakenke District

Joseph Dusabimana[1] and Leon Rugema Mugabo[2]

## Abstract

This study investigates how physics teachers of lower secondary schools practice inquiry-based teaching and learning (IBTL) in their physics teaching. The study used qualitative techniques such as open-ended questionnaires, interviews, and observation to collect data. The study participants were three senior-one physics teachers purposefully selected from three lower secondary schools of Gakenke District located in the Northern Province of Rwanda. Collected data were analyzed using content analysis. The study's findings revealed that study participants know about and how IBTL should be implemented. However, they were limited only on traditional methods of teaching and did not tackle five practices of inquiry-based teaching and learning in their physics teaching, which include engaging students in scientifically oriented questions, allowing students to give priority to evidence, allowing students to give explanations from evidence, and to communicate and justify their explanations and evaluating explanations from evidence. Therefore, teachers were found not effectively implementing the current competence-based curriculum (CBC) in Rwanda. Teachers are recommended to ask questions that require students to compare and contrast for practicing inquiry practice of evaluating explanations from evidence and to allow students to use different sources of information rather than using physics books only.

Keywords competence-based curriculum; inquiry-based teaching and learning, physics teachers; secondary school physics

## Introduction

Any country may change its educational curriculum depending on its goal of education. It is in this regard in the year 2015, Rwanda has shifted from a knowledge-based curriculum (KBC) to a competence-based curriculum (CBC) designed for providing students knowledge, skills, and competencies that allow them to take part in the socio-economic development of the country (REB, 2015a). To achieve the effective use of revised curriculum, teachers have to move from the use of teacher-centered teaching methods to student-centered methods of teaching, such as inquiry-based teaching and learning (IBTL).

By adopting this revised curriculum in Rwanda, a few studies were conducted on the use of inquiry-based instruction in physics teaching. In a study conducted for examining the understanding and practices of mathematics and science teachers on student-centered education in nine secondary schools of Rwanda, Nsengimana et al. (2017) confirmed the shortage of studies related to IBTL. However, Mugabo (2015) investigated the understanding of Rwandan lower secondary school science teachers

[1]Joseph Dusabimana, African Center of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda College of Education (UR-CE), Kayonza, RWANDA, P.O. Box: 55 Rwamagana. Email: josephdusabimana15@gmail.com, Phone: +250785551143

[2]Leon Rugema Mugabo, University of Rwanda-College of Education (UR-CE), Kayonza, RWANDA, P.O. Box: 55 Rwamagana. Email: mugabol2000@yahoo.com, Phone: +250788522916

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about IBTL as one aspect of CBC and found a gab linking them. In Rwanda, few studies are related to the use of IBTL in physics teaching. Therefore, this study comes to fill this research gap.

*Meaning of inquiry-based teaching and learning (IBTL)*

The term inquiry-based teaching and learning (IBTL) takes origin from the constructivism theory of John Dewey, which focuses on students' creation of new knowledge based on their initial learning experiences. It is defined and described by different scholars in different ways. For example, NRC (1996) states that: *Inquiry-based teaching and learning is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations; and communicating the results (p.23*).

Similarly, in the words of Petr (2010): *Inquiry-based teaching and learning is a type of instruction during which the knowledge is generated during solving of a certain problem in consecutive steps that include the setting of the hypothesis, choosing suitable methods to investigate a certain phenomenon, obtaining the results and their processing, conclusion, discussion and very often cooperation with colleagues-pupils as well (p.139).*

Windschitl (2003) states that IBTL is a process composed of four levels organized from the lowest to the highest level as follow: the first level is called confirmation experiences; at this level, the question under investigation, reply, and instructions to follow for reproducing data are given to students to verify the recognized statement. This level is the lowest level of inquiry as students need to be directed more by the teacher. The second level of inquiry is a structured investigation or planned inquiry. At this second level, the teacher gives the question to investigate and instructions to find the answer. The third level is called guided inquiry. At this level, the question to investigate is given to students by the teacher, while the methods used to find out the answer are proposed by the students. The fourth level, the last level, is called open inquiry; at this level, both research questions and methods used for finding the answer are formulated by students themselves.

*IBTL as an active learning technique*

Dostál (2015) defines IBTL as an active teaching approach that emphasizes posing educational problems and is based on the constructivist method of education. IBTL refers to a learner-centered approach in which learners themselves take responsibility for their learning by questioning, examining, and proving answers (Caswell & LaBrie, 2017), where learners are predicted to answer the questions under investigation by analyzing collected data and sharing ideas (Bell et al., 2005). It is also known as a system of teaching and learning that helps the learner develop the skills of solving the problem and critical thinking skills (Maxwel , Lambeth & Cox, 2015). Thus, IBTL is a process where students are involved in their learning, formulate questions, investigate widely and then build new understandings, meanings, and knowledge.

*IBTL as a learner-centered approach*

According to Chu et al. (2007), inquiry-based teaching and learning are one of the student-centered approaches which emphasizes

questioning, the skills of thinking critically, and the skills solving problems. Note that it was revealed that during IBTL implementation, the teacher involves students in expressing the question in precise form (Chu et al., 2007). Specifically, Hofmann (2004) defines inquiry-based teaching and learning as a teaching approach that involves students actively in the process of creating knowledge through answering questions within an environment that contains the resources needed during that process, while Njagi (2016) defines it as a teaching method in which a tutor allows students to study science by conducting their personal research through observation and tangible experiences, formulating hypotheses, scheming experiments, carrying out their personal schemed experiments, scrutinizing and debating the findings from experiments and sharing outcomes. Therefore, basing on the views of various authors, inquiry-based teaching and learning is a teaching approach focusing on asking the question, conducting an investigation for getting data necessary to answer asked questions, and communicating the findings from the investigation.

*Teachers' responsibilities when teaching physics using IBTL*

During teaching using the inquiry approach, teachers have several responsibilities, as reported by various researchers. It encompasses teaching students scientific procedures and skills applied by scientists when learning about the world and applying the skills involved with learning scientific notions (Mineo et al., 2010). Authors also reported that in inquiry-based teaching and learning of science including physics, the teacher's responsibility is helping students to put into practice the scientific procedures by instigating the problem planned to learn scientific notions. Thus,

IBTL of physics requires teachers to provide students guidance until they discover the physics phenomena predetermined by the teachers (McBride et al., 2004). Also, Ahmed (2018) reported that teacher direction is crucial in the inquiry-based teaching and learning process. The study conducted by Aulls and Shore (2008) reveals that the role of the teachers in IBTL of physics differ from the roles they play in the traditional method of teaching. In their study, they confirmed that teachers' role in this approach is to stimulate students' interest to participate in the parts of inquiry, including experiments, projects, hypothesizing, and laboratories, while the role of teachers in the traditional method of teaching is to transmit knowledge to passive students (Nzeyimana & Ndihokubwayo, 2019). Aulls and Shore propose that during teaching using IBTL, teachers have to shift from instructor role to facilitator role, and students would shift from passive status to an active status while learning. Therefore, referring to the views of the above-cited researchers, the teacher would play a role in facilitating students' learning when teaching physics using inquiry-based teaching and learning approach.

*Features of IBTL in competence-based curriculum (CBC) implementation*

A few years ago, Rwanda started to use the competence-based curriculum (CBC) in schools (REB, 2015b). Students needed knowledge and skills, and attitudes that could enable them to participate in socio-economic development by focusing on teaching science and technology (Mugabo, 2015). That CBC replaced the knowledge-based curriculum (KBC), which focused on thought and passivity rather than action and active teaching methodology (Ndihokubwayo & Habiyaremye, 2018). In addition, in KBC, the teacher was considered as an expert while the student was taken as someone who did not possess knowledge. In this regard, the student was supposed to sit within the classroom, hear the teacher's talks, copy the

notes provided by the teacher from the blackboard, and learn by repetition.

The competence-based curriculum differs from the knowledge-based curriculum in the fact that it considers the level of a student when designing the content to be taught in each level of education, initial knowledge of the student as well teaching methodology used to deliver the content. Teaching methodology focuses on a student-centered approach, including inquiry-based teaching and learning. Students create flexible knowledge that can be applied in real life through personal investigation group work discussion under the direction of the teacher.

Sullivan's (2008) study reveals that inquiry-based teaching and learning (IBTL) allows students to participate in various activities using their hands to explore science concepts and gain scientific skills. It can be well noted that inquiry instruction provides students the guidance to understand the world around them and formulates the new information using analytical methods (Kennedy, 2013). Njagi's (2016) study argues that IBTL provides students the chance to gain skills necessary to solve their real real-life problems and deal with issues that have unclear answers. He also stated that when a teacher allows students to create knowledge through inquiry, the students may get expanded skills of solving problems. And the conversion of knowledge into skills is what CBC intends. Therefore, IBTL is a hot potato that teachers in Rwanda should adopt to implement the current curriculum well.

*Role and significance of IBTL in students learning and performance*

Inquiry-based instruction is the tool used to increase students' motivation; it helps learners satisfy their needs in terms of knowledge and develop meta-cognitive skills, including critical thinking skills and problem-solving skills (Minner et al., 2009). Students involved in the inquiry process get both writing and verbal communication skills through discussions with their group members, making reports of the findings from the investigation, and sharing their research findings. The study conducted by Chamundeswari and Bakiaraj (2015) reported that IBTL, like other active teaching methods, increases students' performance in physics. Also, Eviota and Liangco's (2020) study aimed to investigate the impact of using inquiry-based instruction on students' performance revealed that such instruction can contribute to students' retention of physics concepts and increase students' performance in physics subjects. Singh and Kaushik (2020) study investigated the effectiveness of using IBTL instruction on learners' performance, confirming that it is the best method that helps learners learn many concepts of science and increases critical thinking learners and their performance.

Inquiry-based teaching and learning help students gain skills that help them understand the real world (Njagi, 2016). Aulls and Shore (2008) found that inquiry-based instruction stimulates students' motivation to learn independently, enriches their critical thinking and problem-solving skills, promotes their understanding of scientific concepts, curiosity, and increases their self-confidence and teamwork. AAAS (1993) revealed that IBTL instruction is the best way to achieve science literacy because it allows students to discuss scientific ideas.

The study of Purser and Renner (1983) reported that IBTL is crucial in the implementation of CBC as it gives more direction to students who do not prepare well to deal with the problems of inquiry without

prompts and teaching due to lack of familiarity or because they have not attained cognitive level needed for thinking abstract things. Inquiry-based teaching and learning increase students' achievement in acquiring content knowledge of science, understanding scientific notions, and overcoming students' misconceptions (Basaga, 1994). Most research conducted on IBTL reported that it provides students a clear understanding of the nature of scientific knowledge and that it is a dominant tool for developing scientific thinking strategies and a deep understanding of the content of science (Ben-David & Zohar, 2009).

Hmelo-Silver (2004) confirmed that inquiry-based teaching and learning helps students acquire knowledge and skills, including solving their problems. Several studies conducted to verify the usefulness of IBTL in teaching and learning physics revealed improved academic achievement among students and made them lifelong learning students. The study of Leonard and Penick (2000) argued that students learn through inquiry rather than learning about inquiry; however, some teachers do not understand how the inquiry process can be conducted effectively.

Sogillo et al. (2016) reported that inquiry-based teaching and learning help students without special needs; it was found to help them develop positive ideas, creativity and become independent learners. Inquiry-based teaching and learning (IBTL) was found to allow students to interact with materials, models, manipulate variables, explore phenomena, and attempt to apply principles affords them with opportunities to notice patterns, discover their underlying causalities, and learn in ways that are seemingly more robust (Alfieri et al., 2011). According to Montiel-Overall (2012), students develop different skills, including reading skills, making presentations, information, and computer skills through the IBTL approach. This teaching and learning approach takes its origin from social constructivist theory, and it has the central focus of competence-based curriculum worldwide (Aulls et al., 2016). Inquiry instruction is characterized by the following five features: (i) engage students in scientifically oriented questions, (ii) students provide priority to evidence, (iii) students formulate explanations from their gathered information, (iv) students evaluate explanations in light of alternative explanations, and (v) students share and make justification of their explanations (NRC, 2000).

As described by National Research Center (NRC, 2000), scientific classroom inquiry in physics education is a process of developing an understanding of the concepts of science through identification and examination of the problems, hypotheses formulation and predictions, preparing, managing, and conducting research with a purpose of obtaining evidence, analyzing and valuing data, interpreting outcomes, formulating explanations, constructing based on models, formulating argumentation basing on evidence, and sharing scientifically in various and at all stages of the process of inquiry. Thus, from the above views from various studies, it can be inferred that IBTL has a crucial role for effective students' learning of science, including physics, as it helps them to understand scientific concepts, to acquire crucial skills such as communication skills, writing skills, problem-solving skills, critical thinking skills and that it helps students to overcome their misconceptions related to scientific concepts.

**Aim and significance of the study**

It aimed to investigate and analyze how Rwandan physics teachers implement a competence-based curriculum through inquiry-based teaching and learning. The study is guided by the following research

question: *How do Gakenke lower secondary school physics teachers practice inquiry-based teaching and learning in their physics teaching?* The study outcome would inform policymakers to improve CBC training-related active teaching techniques. It would educate researchers on the gap and bring effective teaching techniques as remedial.

## Methodology

This study used a qualitative research design (Fraenkel et al., 2012). It was used for getting a deeper understanding of how physics teachers practiced inquiry-based teaching and learning (IBTL) during the implementation of a competence-based curriculum (CBC).

### *Selection of study participants and schools*

The study used a sample of three teachers selected from three distinctive schools of Gakenke District in Rwanda. A purposive sampling technique was used. The selected school had to be public schools supported by the government, placed in an environment that is accessible in terms of transport. It had to have an ordinary level (senior one to senior three). Study participants had to be each senior physics teacher from selected schools. The study was conducted only in three secondary schools due to the time limit and funds.

### *Data collection*

This study got ethical clearance from the research and innovation unit at the University of Rwanda College of Education (UR-CE). Participants were ensured secure to participate in the study and understood the rationale and purpose of the study. Data were gathered using open-ended questionnaires, interviews, and observations, and it was completed in seven days for each selected school. Those seven days included one day for delivering questionnaires, one day for conducting the interview, and five days for classroom observation. Those three different tools were used for getting valid data. Ended-open questionnaires were given to participants for writing down and describing inquiry practices used in classroom teaching. The interview was conducted to provide detailed explanations of inquiry practices given through questionnaires.

In contrast, classroom observation was conducted to assess whether the practices of inquiry reported by study participants through questionnaires and interviews were being put into practice during classroom teaching. Field notes were taken while conducting the interview and classroom observation. All the instruments passed through validation check by educationists at UR-CE. At the same time, a pilot study was conducted in two schools of Gakenke to ensure the validity of the tools. The whole data collection process was done from 6 May to 11 June 2021.

### *Data analysis and presentation*

Data were analyzed using content analysis (Orodho et al., 2016). Major themes were induced from the questionnaire data while; interviews and observations supplemented it. Data were grouped into categories/themes and coded based on their similarities. Thus, data analyzed from the above three listed tools were presented using the triangulation method to ensure the reliability of information from participants.

## Findings and Discussion

To accomplish the purpose of the study, participants were given questionnaires for filling all activities they go through when teaching using inquiry-based teaching and learning in their physics teaching. Then, they were requested to attend an interview to

describe their inquiry practices given through questionnaires. The inquiry practices given by the study participants through both questionnaires and interviews are similar. All participants reported that they: put students in groups, gave students the questions related to physics concepts, gave students the required materials, gave students instructions to follow during the collection of data used to address physics questions, allowed students to collect data by following given instructions and asking students to present the findings from the research (see Table 1).

**Table 1 Themes related to IBTL depicted from teacher questionnaire**

| THEMES | TEACHER 1 | TEACHER 2 | TEACHER 3 |
|---|---|---|---|
| **1. Teachers' understanding of inquiry-based teaching and learning (IBTL).** | IBTL is a form of active learning and teaching that starts by asking questions, problem-solving, etc. It allows students to take ownership of their learning and increases engagement with the content. | IBTL is an approach to teaching and learning that emphasizes the students' role in learning. In this approach, students develop questions that they are curious to answer. It can also be defined as learning through research. | IBTL is an approach based on learners' activities involving them in their learning process, such as asking questions, conducting experiment and reporting the findings from conducted experiment |
| **2. Activities that teachers go through when using IBTL in physics teaching.** | -Give students the protocol of experiment and ask them to make presentation of the results from an experiment<br>-Give learners a group work an and ask them to interpret and report their answers | Giving students physics questions that allow them to:<br>- Make observation<br>- Make analysis of the results from observation<br>- Interpret and present the results from observation | - Give learners the opportunity to investigate a problem for getting possible solutions<br>-Allow make students to make observations<br>-Allow students to ask questions<br>-Simulate motivation of students to think critically<br>-Allow students to test ideas |
| **3. Contribution of IBTL in implementing a physics competence-based curriculum (CBC).** | -It enhances comprehension rather than memorization<br>-It allows students to develop their understanding during the learning process and increases their | - Learners develop questions that they are curious about<br>-Research the topic during class time<br>-Ask students to reflect on what worked about | -It challenges students' thinking by engaging them in investigation scientifically about the oriented questions<br>-Evaluate explanations in light of alternative explanations |

| THEMES | TEACHER 1 | TEACHER 2 | TEACHER 3 |
|---|---|---|---|
| | engagement with physics content<br>-It emphasizes students' ideas and encourages them to discuss ideas among their peers | the process<br>-Have students present what they learned | -It enhances communication skills of learners<br>-It allows students to take ownership of their education |
| **4. Frequency of use of IBTL in the physics classroom.** | Sometimes | Sometimes | Sometimes |
| **5. Main challenges teachers face while using IBTL.** | -Lack of students' books and teachers' guide in a physics lesson<br>-Poor understanding of students of what teacher ask for<br>-Lack of smart classroom to do research for both teachers and learners<br>-Being shy of learners to speak publicly<br>-Time constraints<br>-Lack of laboratory | -Unavailability of appropriate textbook and classroom resources<br>-Low level of students' expression in medium language<br>-short period of time<br>-The preparation and training of science teachers work place and skills<br>-Time management<br>-Beliefs of some students that physics is difficult subject | -Learners do not have some knowledge about some topic in physics<br>-Lack of some teaching materials (teaching aids)<br>-Low level of language to express themselves<br>-The use of IBTL is time consuming compared to the time allowed to a given unit |

In addition, all teachers reported that they facilitate students in all the above-listed practices. For example, one teacher said:

> *I form students' groups, give students physics questions, give students the required materials, give students instructions to follow during data collection, ask students to collect data by following given directions for getting solutions to the physics questions, then after I ask students to present their findings. I facilitate students in all the above-listed activities (Teacher 2).*

Five main features characterize ideal classroom inquiry: i) engaging students in scientifically oriented questions. Questions could be formulated either by students themselves or teachers. ii) Students give priority to evidence. For this second feature of classroom inquiry, the teacher should allow students to develop explanations that can address formulated questions in the first

feature of inquiry. Here, students have to read different materials or conduct an experiment to get data used to address scientifically oriented questions. iii) Students formulate explanations from evidence. In this third feature of classroom inquiry, students answer scientifically oriented questions using collected data from an experiment or other sources. iv) Students have to evaluate their given explanations from the collected information to see whether they fit the existing evidence. v) Students share and defend their explanations; (NRC, 2000; Walker, 2007). However, teachers in our study did not implement these IBTL processes; rather, they followed teacher-centered processes (see Table 2). Note that where the practice was not observed was described as "not applied".

**Table 2 Classroom observation practices**

| IBTL Process | Teacher 1 | Teacher 2 | Teacher 3 |
|---|---|---|---|
| **1. Engaging students in scientific oriented questions** | not applied | not applied | not applied |
| **2. Providing priority to evidence** | not applied | not applied | not applied |
| **3. Formulating explanations from evidence** | not applied | not applied | not applied |
| **4. Evaluation of explanations in light of alternative explanations** | not applied | not applied | not applied |
| **5. Communicating and\justifying explanations** | not applied | not applied | not applied |
| **6. Teacher disseminates information to passive students** | -The teacher transmits knowledge to students<br>-Most students are passive as the teacher asks only students who raised hands | The teacher stands in front of silent students and gives his prepared notes to them | -The teacher is transmitting knowledge to passive students |
| **7. Teacher plays an authoritative role** | The teacher dominates all classroom activities, including classroom discussions, setting questions, and solving | The teacher heads all teaching and learning activities. For instance, a student to share his/her ideas with his/her | The teacher dominates classroom discussions during teaching and learning while students are kept silent until they |

| IBTL Process | Teacher 1 | Teacher 2 | Teacher 3 |
|---|---|---|---|
| | them himself | classmate must first get permission from the teacher | will get permission from the teacher in order to talk |
| **8. Teacher does not allow students trial and errors** | The teacher does not allow students to make many trials; a student whose answer is correct is only the one who gets appreciation from the teacher | The teacher does not provide an appreciation to a student who provides the wrong answer and does not provide him/her the chance to retry. Appreciation from the teacher is given to a student whose answer is true | The teacher does not allow students to try many times; a student whose answer is correct is only the one who gets immaterial rewards from the teacher |
| **9. Students work individually** | The teacher motivates students to find the answers individually and requests the one who gets the answer in order to provide his/ her answer | For any item that the teacher asks, the student is supposed to find the answer independently instead of finding the answer through group discussion | The students were encouraged to think and find out solutions to provided questions separately |
| **10. Students are busy taking notes provided by the teacher** | During teaching and learning, the teacher stands in front of students writing her talks while students are passively following the teacher's talks and copying exactly the teacher's notes | Most of the classroom time, passively, students are busy hearing teacher talks and write these talks | During the classroom, students are silently busy writing teacher's talks and notes |

Classroom observation revealed that teachers who participated in the study allowed students to ask short answers to physics questions, ask questions, conduct investigations, and explain ideas in their respective groups. Observation also revealed that the study participants allowed students to communicate ideas through group presentations. For examples:

> *Teacher 1 entered in the class and wrote the title of the lesson which was a force. He moved a table and told to students that the table was moved due to the applied force. He explained the definition of force as well as the properties of force*

*while students wrote down explanations given by teacher 1 (Teacher 1, classroom lesson observation 2, on 19-05-2021).*

*Teacher 2 reached in the class with a mirror in his hand. He showed students the mirror and told to them that the lesson of the day was a plane mirror. He explained what means by a plane mirror and types of mirror. Then after students were given prepared notes to write in their notebooks (Teacher 2, classroom lesson observation 3, on 21-05-2021).*

*Teacher 3 come in the classroom and write the tile of the lesson after greeting students; the tile of that lesson was state of matter. She explained what is meant by matter, listed study 3 states of matters (solid, liquid and gas) and their properties. She left prepared notes to be taken by students (Teacher 3, classroom observation on 2, 20-05-2021).*

Our findings compromise with Mugabo's (2012) findings, who found that teachers in lower secondary schools knew a little about IBTL. However, our study shows that teachers know the stages of IBTL and its role in improving active learning; however, they do not implement it in the classroom. Our findings contradict those of Ndihokubwayo et al. (2020), who found that physics CBC is on a good track using reformed teaching observational protocol. However, they found later that teachers plan for low levels of Bloom's cognitive and affective taxonomy domains and do not follow effective inquiry techniques along the stages of the lesson activities (Ndihokubwayo, Ndayambaje, et al., 2020). However, our findings are in agreement with (Uwizeyimana et al., 2018) findings, who found that physics teaching and learning in Rwanda is generally still dominated by teacher-centered methods which do not allow students to learn actively.

## Conclusion and recommendation

From the study findings, it can be concluded that the teachers were limited only on traditional methods of teaching and did not tackle five practices of inquiry-based teaching and learning in their physics teaching, which include engaging students in scientifically oriented questions, allowing students to give priority to evidence, allowing students to give explanations from evidence and allowing students to communicate and justify their explanations. However, they know about it and know how to implement it as interview revealed. It can also be concluded that the study participants did not use inquiry practices that can allow students to evaluate their explanations from evidence, and students were limited to conduct investigations in books only rather than using other sources of information. The study was made the following recommendations to study participants for effective implementation of inquiry-based teaching and learning in their physics teaching. Ask questions that require students to compare and contrast for allowing them to practice inquiry practice of evaluating their explanations from evidence. Allow students to use different sources of information rather than using books only.

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