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Analysis of Lesson Plans from Rwandan Physics Teachers

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Abstract. Lesson planning is a crucial roadmap guiding the teacher before the implementation of the lesson. In the current study, we aimed at reviewing pedagogical documents used by Rwandan physics teachers. We gathered 32 lesson plans related to optics topics from five teachers and analyzed them using the lesson plan analysis protocol (LPAP) and lesson plan evaluation form (LPEF) jointly. We have found that teachers do not prepare these documents as required by the newly introduced competence-based curriculum. 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. A detailed discussion on each teacher's practice was provided, and we hope it can serve as a qualitative overview on teaching and learning planning for effective classroom implementation. Due to the importance of pedagogical documents on effective teaching, we went through a rigorous validation process and suggested a model lesson plan to be consulted by any physics teacher (please see Appendix C). We recommend that teachers consult this lesson plan and prepare accordingly before class.

Keywords: pedagogical document; lesson plan; physics teacher; competence-based curriculum

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1. Introduction

Any teacher in any subject needs to prepare the lesson before implementing it in the classroom. There are many types of pedagogical documents that teachers need as their daily instruments. These include the scheme of work, lesson plan, class diary, mark sheet, attendance list, notebook, evaluation notebook, exercise notebook, and so forth. However, these documents are importantly used for different purposes according to different teachers and education systems across the world. A system of training teachers in the Rwandan education system date back to colonialism around the 1900s, when formal education was introduced. Before competence-based curriculum (CBC), the knowledge-based curriculum (KBC) also emphasized much on effective PDs. However, the current CBC (REB, 2015b) focuses on learner-centered as one of the millennium development goals implemented in 2000 (Abbott, Sapsford & Rwirahira, 2015; Nsengimana et al., 2020). As of 2016, all teachers were required to shift from knowledge-based approaches and adapt to competence-based approaches. Except for content knowledge, others related to pedagogical knowledge, instructional tool, and methods have all shifted towards learner engagement related approaches, including the ways of preparing PDs.

Pedagogical documents are essential because they guide teachers to the expected destination. For instance, the work (SW) scheme guides teachers in a whole year or term (REB, 2015c). SW focuses on unit planning, while lesson plan (LP) focuses on topic planning (REB, 2015a). SW consists of what a teacher will teach in a term. It is a well-scheduled document in the form of a bunch of lessons, while an LP is a sheet of paper showing what the teacher will follow during a class of one or two periods (REB, 2017). Jacobs, Martin, and Otieno (2008) refer to a lesson plan to a teacher's day-to-day teaching practice focusing on pedagogical knowledge. PDs are vital because they guide teachers' daily work. The scheme of work should be well prepared to guide the teacher to schedule the lesson for an extended time frame, while a lesson plan should be well prepared to reflect what will be done in a real classroom. An investigation carried out in Rwanda during learning optics showed the low performance and conceptual understanding of geometric optics (Ndihokubwayo, Uwamahoro & Ndayambaje, 2020a) and physical optics (Ndihokubwayo et al., 2020). Therefore, we were interested in analyzing these documents used by some physics teachers to check the way teachers prepare their PDs, mainly LPs. Planning is key for any teacher for his/her professional development (Ruys, van Keer & Aelterman, 2012). Pramoolsook and Magday (2019) and Sawyer and Myers (2018) assume that a lesson plan is a precise reflection of what arises in the classroom. Thus, a link between teacher's planning and students' outcome should arise. This study will help teachers to value the preparation before the class takes place using various LP tools. Teachers generally prepare the lesson plans for evaluation purposes by school administrators (Causton-Theoharis, Theoharis & Trezek, 2008; Sawyer & Myers, 2018; Theoharis & Causton-Theoharis, 2011), such as monitoring classroom curriculum implementation. However, they can serve as a roadmap to teachers for effective classroom implementation. They can also ensure that lesson plans are available and clear for substitutes in case the teacher is absent (Jacobs et al., 2008). The LPs include references to page numbers to be covered in the textbook, problems to be assigned as homework, and lists of standards or objectives to be covered during the lesson delivery.

The use of both lesson plan analysis protocol (LPAP) and lesson plan evaluation form (LPEF) is limited to LP only. Therefore, classroom observation should serve as a supplement to obtain data about the program under investigation. The lesson plan tools are used to prescribe the components of a program in terms of established models quantitatively and help determine the program's level of implementation (Boikhutso, 2010; Pramoolsook & Magday, 2019). A lesson plan analysis tool is a scalable and broader lens to support other tools that measure teaching behavior, such as classroom observation. However, it does not show evidence about lesson enactment until post-lesson information is delivered (Diem & Thathong, 2019; Jacobs et al., 2008).

1.1 Research problem

It is essential to check what was planned before observation. The literature shows a strong relationship between teacher planning and student outcomes, as it is assumed that the teacher's lesson plan reflects the classroom activity (JICA, 2020). Therefore, LPs would be useful in program evaluation, such as tracking CBC implementation and teacher assessment. The SIIQS† project initiated lesson plan analysis through lesson study activity in Rwanda; however, there have been no studies evaluated of lesson plans for the physics CBC. Consecutive studies done in Rwanda found gaps both in pedagogical document preparation and classroom teaching practices. For instance, Byusa, Kampire, and Mwesigye (2020) found that the teachers do not take the PDs as their guide; instead, they only care about presenting them to education authorities such as district education officers, headteachers, or deputy headteacher in charge of studies. Ndihokubwayo, Uwamahoro and Ndayambaje (2020b) observed 42 physics classes using the RTOP tool and found that reformed teaching is 53% and teachers are running out of time and do not care about inquiry instruction. Nowadays, the inquiry is gradually receiving considerable room in many developing countries' science curriculum though it is at its early stage in Rwanda (Mugabo, 2012).

1.2 Research questions

This study aims at reviewing Rwandan physics teachers' lesson plans in line with the following research questions:

i) To what extent do physics teachers' lesson plans reflect on a competence-based curriculum?
ii) How do physics teachers prepare their lesson plans based on cognitive and practical Bloom Taxonomy's domains?
iii) Do physics teachers introduce inquiry-based planned instruction in their lesson plans?

This study bridges the gap between teacher lesson preparation and real classroom practices. It shows teachers an effective way of lesson planning. Therefore, we hypothesize that there will be no difference among teachers in terms of lesson preparation. This research's novelty is that we designed and validated a model lesson plan that any teacher can refer to.

† SIIQS: Project for Supporting Institutionalizing and Improving the Quality of School-Based In-service Teacher Training Activity

2. Methods and Procedures

This is basic and applied research (Orodho et al., 2016). It is basic in a way that it adds knowledge of Rwandan physics teachers' lesson planning to existing literature while is applied in a way that we have designed a model lesson plan for teachers' references. We have used a mixed methodology to present the data. Thus, we have documented the characteristics of the lesson plans and discussed the variability among teachers.

2.1 Sample scope

To carry out this study, we got an ethical clearance from the research and innovation unit at the University of Rwanda College of Education (URCE) for and research permission from distinguished districts. We, in May 2019, have visited two schools in Kigali and the Eastern province, Rwanda. Our sample targeted 11 physics teachers from four districts in Rwanda selected purposively from schools accommodating advanced level—grade 10 and 11—science, including physics subject. We invited them to share with us the taught lesson plans related to optics. These LPs should have been used in the last term (from middle January and early April 2019). Eight teachers shared with us their lesson plans in hand or online. Three of eight teachers shared the LPs that are not relevant. One teacher shared mathematics LPs; two teachers shared LPs of mechanics related topics such as "Kinematics and simple harmonic motion," "Simple harmonic oscillation (Simple pendulum)," "Simple harmonic oscillator (Mass suspended from a coiled spring)" and "Representation, characteristics, and properties of sounds waves." Among these two teachers, one shared LPs related to optics but from 2018. We did not consider all of these LPs from three teachers for our analysis. Thus, our analysis took a case of five physics teachers' lesson plans. We have collected 32 LPs, representing approximately 54% of the sampled teachers (Appendix A).

2.2 Data sources

We used two necessary LP analysis tools to carry out this study. The LPAP of Ndihokubwayo et al. (2020) and the LPEF of Ferrell (1992). LPAP analyses nine elements of a competence-based lesson plan. These 9 LPAP elements consist 27 items (Ndihokubway et al., 2020). The nine elements are sub-sectioned into three stages: preliminary elements, the body of the content, and the accessories. "A Lesson Plan Evaluation Form (LPEF) was developed to provide systematic quantitative data about classroom functioning (Ferrel 1992, p. 23)." The LPEF involves three models—curriculum, Bloom Taxonomy domains, and inquiry techniques—of learning used in developing a curriculum where each lesson plan is scrutinized to determine the level to which it reflected the discerned curriculum elements (Ferrell, 1992). The developer of LPEF used the Inquiry Model to weigh the degree to which the LPs reflected a chance to gather and organize data and formulate and test hypotheses. The LPAP components align with LP format for a competence-based curriculum (REB, 2019) while LPEF calls upon the inquiry-based physics instruction (Ferrell, 1992) and illuminates the outcome from teacher planned teaching practices.

2.3 Reliability analysis

In analyzing these 32 LPs, we read all the documents and classified them according to the reserved scales (see Table 1). We used SPSS version 23.0 to analyze both reliability tests and data presented in the results section.

Table 1: LPAP scales (Ndihokubwayo et al., 2020)

	Explanation	Scale 1	Scale 2	Scale 3	Scale 4
Item1	Related to Key Unit Competence (KUC)	Not written	Written but not related to syllabus	Written in summary and related to syllabus	Written in full and related to syllabus
Item2	Related to the format of the lesson title	More than three	Triple	Double title	Single title
Item3-4	Relationship between lesson title and time, and the connection to the syllabus	Definitely not	Probably not	Probably yes	Definitely yes
Item5	Related to Instructional Objective (IO)	Not written	Written but Not related to the topic	Written and related to the topic	Written and related to the topic and content
Item6	Number of IO components	None	One to two	Three to four	All five
Item7	Related to Special Education Needs (SEN)	Not written	"none" or "-" or the teacher writes a number only	Describe only	Write the number and describe
Item8	Addressing SEN	Not addressed	Not clear where it was addressed	Addressed in IO or Description of Teaching and Learning Activity (DTLA)	Addressed in Introduction to the lesson (Intro), or Lesson development (Dev), or Conclusion of the lesson (Concl))
Item9	Related to DTLA	Not written	Written but not related	Written but does not show well what will be done in the lesson	Written and shows well what will be done in the lesson
Item10-12	Writing the content of the lesson	Not written	Written but unclear (or not related)	Written but not describe (outline)	Written and well described
Item13-14	Stages of the development and conclusion sections	Components outlined in "Note" are absent	Not clear/not identifiable	Other components apart from those outlined in "Note."	Components outlined in "Note" are present
Item15-23	Teaching resources (TR), Formative assessment (FA), Active learning techniques (ALT)in the content of the lesson	Not visualized	Visualized but not clear	At least one is visualized and clear	More than one is visualized and clear
Item24	If visualized, was the ALT used with purpose?	Definitely not	Probably not	Probably yes	Definitely yes
Item25-26	Generic competences (GCs) and Cross-cutting issues (CCIs)	Not written	Not clear	Outlined only	Outlined and described
Item27	Teacher self-evaluation (TSE)	Not written	Written but not clear	The teacher writes a simple word "well or not well done"	The teacher well describes with the next step

The criterion validity check has shown that the data from the LPAP were consistent with data from other more standardized evaluation tools such as Lesson Plan Evaluation Form (LPEF) and Science Lesson Plan Analysis Instrument (SLPAI). A positive correlation (Pearson product-moment coefficient $r > .50$) was detected across "Lesson approaches" of LPAP, "Inquiry techniques" of LPEF, and "Student inquiry" of the SLPAI items.

Each lesson plan was assigned a number and separately rated by two raters from the African Center of Excellence for Innovative Teaching and Learning of Mathematics and Science (ACEITLMS) based at the University of Rwanda College of Education (URCE); among them, one is the first author of this study. These raters are experienced in analyzing lesson plans and are familiar with the LPAP.

The Spearman's rho among the raters was computed and found to be .81, while the weighted kappa was found to be .72 across 27 LPAP items. Thus, the raters did not differ in the way in which they rated the lesson plans.

The preliminaries (item1-9) got a reliability coefficient of .92 (and a weighted Kappa of .87) across 32 LPs averaged from two raters. The body of the content (item 10-24) got a reliability coefficient of .79 (and a weighted Kappa of .69), while the accessories (item 25-27) got .58 (and a weighted Kappa of .48). Table 2 presents detailed interrater reliability among 9 LPAP elements.

Table 2: Interrater reliability statistics across LPAP elements

LPAP elements	**Spearman's rho**	**Weighted Kappa (K)**
Key unit competence	0.871	0.875
Title of the lesson	0.857	0.742
Instructional objective	0.969	0.968
Special Education Needs	1	1
Lesson description (DTLA)	0.897	0.758
Lesson stages	0.412	0.324
Lesson approaches	0.980	0.869
Generic competences and Cross-cutting issues	0.369	0.214
Lesson evaluation	1	1

The inter-rater reliability for LPEF was similarly based on the same LPAP raters scoring a sample of the same 32 LPs. The Spearman's rho among the raters was computed and found to be .93, while the weighted Kappa was found to be .79 across all selected LPEF items.

Alongside rate agreement among raters, Cohen's Kappa is used to remove agreement by chance (Cohen, 1988). Its interpretation is moderate when K is >.5, reasonable when K is >.7, and excellent when K is >.8. For ordinal data, the Spearman-Brown coefficient is considered, and a weighted Kappa is computed to provide an ordinal outcome.

To supplement our study results, we have crafted and validated a model lesson plan that any physics teacher can refer to (see Appendix C).

3. Data Analysis and Results

Each rater has rated all 32 LPs into four LPAP scales according to each of the 27 LPAP items. We have averaged the results from both raters and computed means for each item. All teachers did not use the REB LP format. This is the reason why tracking the steps of inquiry techniques was difficult. The new REB LP format appears in the textbooks printed in 2019 (REB, 2019). However, teachers did not yet adapt themselves to it. This may be the lack of emphasis from REB. Teachers should be well informed of their roles. This format has segments in the development and conclusion sections of the LP, where the development section of the LP comprises discovery activities, presentation learners' findings production, and exploitation of findings/production, and the conclusion section comprises conclusion/summary and assessment/homework.

It can be found that there is a variety rate across all 27 items on a 4-point scale. Thus, some items were rated one (on scale 1) while others were rated four (on scale 4). This is to clarify that, for instance, most of the teachers did not write SEN or wrote "none" or "-" or a number only and scored below an average score of 2.0. However, none of this written SEN was addressed in the body of the lesson. Thus, both raters rated this item on scale-1. However, they connect the lesson title to the syllabus—as both raters rated this item into the scale-4. In other words, teachers consult the syllabus in formulating the lesson topic. All teachers write the IO in all the LPs, although they miss some components, mostly condition and standard (see Table 3).

Table 3: LPAP mean scores from two raters

		Mean Rater1	**Mean Rater2**	**Mean Rater1 &2**	**SD Rater1 &2**
Item1	Written KUC and how it is written	3.6	3.7	3.6	0.95
Item2	Format of the lesson title	3.8	3.8	3.8	0.46
Item3	Lesson title time-bound	3.2	3.8	3.5	1.11
Item4	Syllabus connected to the lesson title	4	4	4	0
Item5	Written IO and how it is written	4	4	4	0
Item6	Number of IO components	3.5	3.4	3.5	0.5
Item7	Written SEN and description	1.8	1.8	1.8	0.84
Item8	Addressed SEN and the place where it is addressed	1	1	1	0
Item9	Written DTLA and how it is written	3.1	3.1	3.1	1.31
Item10	Lesson introduction	3.2	3.2	3.2	0.42
Item11	Lesson development	3.5	3.5	3.5	0.5
Item12	Lesson conclusion	3.2	3.2	3.2	0.42
Item13	Components of the lesson development	1.8	1.1	1.4	0.53
Item14	Components of the lesson conclusion	2.1	1.3	1.7	0.91
Item15	TR in Introduction to the lesson	1.3	1.3	1.3	0.67

Item16	TR in Development of the lesson	2.4	2.4	2.4	1.14
Item17	TR in Conclusion of the lesson	1.6	1.6	1.6	0.92
Item18	FA in Introduction to the lesson	2.6	2.7	2.6	0.76
Item19	FA in Development of the lesson	3.1	3.1	3.1	0.64
Item20	FA in Conclusion of the lesson	2.9	3	3	0.28
Item21	ALT in Introduction to the lesson	2.9	2.9	2.9	0.44
Item22	ALT in Development of the lesson	3.1	3.2	3.2	1.01
Item23	ALT in Conclusion of the lesson	3.2	3.2	3.2	0.68
Item24	If visualized, was the ALT used with purpose?	4	2.3	3.1	1.17
Item25	GCs	4	3.7	3.8	0.37
Item26	CCIs	3.9	3.6	3.8	0.62
Item27	TSE	2.6	2.6	2.6	0.83

Active learning techniques (ALT) were mostly provided than formative assessment (FA) and teaching resources (TR) (refer to Appendix B for more detail). They were observed mostly in the Development and Conclusion of the lesson than in the Introduction. This was reflected by the high percentage of LPs in the Development of the lesson (47%) and the Conclusion of the lesson (28%). The TRs were not visualized compared to FA and ALT in both parts of the lesson—Introduction, Development, and Conclusion. This was reflected by the highest percentages of LPs rated into scale 1 "not visualized"—Introduction (87.5%), Development (37.5%), and Conclusion (68.8%) (see Figure 1).

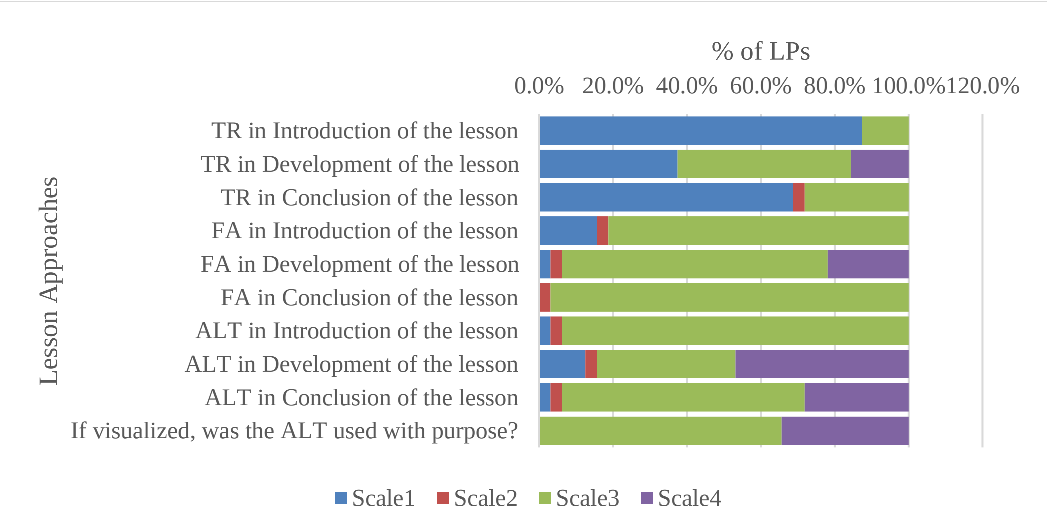

Figure 1: Distribution of LPs into the Lesson Approaches group. Scale-1 "Not visualized" scale-2 "Visualized but not clear" scale-3 "At least one is visualized and clear" scale-4 "More than one is visualized and clear." On the "If visualized, was the ALT used with purpose?" the scale-1 is "Definitely not," scale-2 is "Probably not" scale-3 is "Probably yes," and scale-4 is "Definitely yes."

The descriptive statistics associated with LPAP scales across five physics teachers are reported in Table 4. We evaluated the assumption of normality to satisfy distribution in these five teachers; the Skewness and Kurtosis were found negative. Skew is about distributional symmetry, while Kurtosis is the thickness of the tails and the center of the distribution (Blanca, Arnau, López-Montiel, Bono & Bendayan, 2013). Thus, the data are not normally distributed; instead, they are negatively skewed. Teachers are mostly ranked towards the scale-4 of LPAP. Similarly, the data are negative Kurtosis distribution as the data in distribution is short and wide.

Table 4: Descriptive statistics

	Mean		**Std. Deviation**	**Variance**	**Skewness**	**Kurtosis**
	Statistic	Std. Error	Statistic	Statistic	Statistic	Statistic
MeanTeacher1	2.778	.1945	1.0105	1.021	-.496	-.858
MeanTeacher2	2.926	.1910	.9924	.985	-.691	-.716
MeanTeacher3	2.919	.1803	.9368	.878	-.664	-.370
MeanTeacher4	2.892	.2035	1.0576	1.118	-.655	-.843
MeanTeacher5	2.639	.2182	1.1337	1.285	-.416	-1.253

In order to test the hypothesis that teachers plan their lesson similarly, we performed the correlation analysis and analysis of variances (ANOVA). A .929 Cronbach alpha coefficient was found. Thus, the correlation is highly positive among five teachers. The independent between-groups ANOVA did not yield a statistically significant difference, $F(26, 4)=1.386$, $p=.244$. Thus, we retain a null hypothesis of no difference between teachers in terms of LP preparation. The teachers' means are crossly related, ranging from Teacher 5 (M=2.639) to Teacher 2 (M=2.926).

Among 32 LPs, only four LPs open the Introduction of the lesson by revising the last lesson. This is important from the constructivist point of view in a way that students should build on existing knowledge. Analyzing deep the formative assessment and active learning techniques, we employed the LPEF tool to compute scores on cognitive and affective levels of Bloom taxonomy to respond to the FA and the inquiry techniques as an ALT for most experiment-based LPs. The digits under table 4 are average scores from two raters at a 1-to 4-point Likert type scale from 1 "the item was definitely not appeared" to 4 "the item has definitely appeared."

From the Bloom taxonomy perspectives' cognitive level, teachers plan for only delivering knowledge and assure that understanding is set in. This is shown by the mean score (4.0) across all 32 LPs. Even the application of what was learned was found below the average of 2.0. Similarly, at the adequate level of Bloom taxonomy perspectives, teachers care for making their students receive information (M=4.0) and attend (M=4.0) to and respond (M=3.1) asked questions (see Table 5).

Table 5: Results from the Lesson Plan Evaluation Form 1: Definitely not, 2: Probably not, 3: Probably yes, and 4: Definitely yes

LP code	Cognitive Level of Bloom Taxonomy						Affective Level of Bloom Taxonomy						Inquiry techniques			
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Receiving	Attending	Responding	Valuing	Organization	Characterization	Data collection	Data organization	Hypothesizing	Hypothesis testing
PT1A	4	4	1	2	1	1	4	4	4	1	1	1	1	1	1	1
PT1B	4	4	1	2	1	2	4	4	3	1	1	1	1	1	1	1
PT1C	4	4	1	2	1	2	4	4	3	1	1	1	1	1	1	1
PT1D	4	4	1	1	1	1	4	4	4	1	1	1	1	1	1	1
PT1E	4	4	4	2	2	2	4	4	4	1	3	2				
PT2A	4	4	3	2	1	1	4	4	3	1	3	1	3	3	1	1
PT2B	4	4	3	2	1	1	4	4	3	1	3	1	3	3	1	1
PT2C	4	4	1	1	1	2	4	4	4	1	1	1				
PT2D	4	4	1	1	1	2	4	4	4	1	1	1				
PT2E	4	4	1	1	1	3	4	4	4	1	1	1				
PT2F	4	4	1	1	1	1	4	4	2	1	1	1	1	1	1	1
PT2G	4	4	1	1	1	1	4	4	3	1	1	1				
PT2H	4	4	1	1	1	1	4	4	3	1	1	1				
PT2J	4	4	1	1	1	1	4	4	3	1	1	1				
PT3A	4	4	2	1	1	2	4	4	3	1	1	1				
PT3B	4	4	2	2	1	2	4	4	2	1	2	1	2	3	1	1
PT3C	4	4	1	1	1	1	4	4	3	1	1	1				
PT3D	4	4	2	1	1	2	4	4	4	1	1	1	1	1	1	1

PT3E	4	4	2	1	1	2	4	4	4	1	1	1	1	1	1	1
PT3G	4	4	2	1	1	2	4	4	4	1	1	1	4	3	1	1
PT3I	4	4	3	2	1	2	4	4	4	1	1	1				
PT3K	4	4	3	2	1	2	4	4	4	1	1	1				
PT3M	4	4	2	1	1	1	4	4	2	1	2	1	1	1	1	1
PT3N	4	4	1	1	1	1	4	4	4	1	1	1				
PT4A	4	4	2	2	2	3	4	4	3	3	3	2			4	2
PT4B	4	4	1	1	1	1	4	4	2	1	2	1				
PT4C	4	4	3	2	3	3	4	4	2	4	2	2			3	
PT4D	4	4	3	2	3	3	4	4	2	4	2	2			3	
PT4E	4	4	3	2	3	3	4	4	2	4	2	2			3	
PT4F	4	4	3	2	3	3	4	4	2	4	2	2			3	
PT5A	4	4	1	1	1	1	4	4	2	1	1	1				
PT5B	4	4	2	1	1	3	4	4	2	1	1	1				
Mean	4.0	4.0	1.8	1.4	1.3	1.8	4.0	4.0	3.1	1.4	1.5	1.2	1.7	1.7	1.6	1.1
St. Dev	0.0	0.0	0.9	0.5	0.7	0.8	0.0	0.0	0.8	1.0	0.7	0.4	1.1	1.0	1.1	0.3

The space with no number refers to LPs that were not related to experimentation. We then noted that other LPs would implement inquiry techniques. However, such practice was not visualized. It seems that teachers are not aware of inquiry-based learning techniques and those who are aware of them think that it can only be implemented in experiment related lessons. Our results show that the use of inquiry techniques was below the average of 2.0. Contrary wise, in the Ferrell (1992) study, the LPEF analysis findings indicate that teachers follow an excellent teaching practice during their lesson planning. Only in four LPs, the teacher planned to ask students to hypothesize or predict the outcome of observation (see Table 5). This is in line with a study by Ndihokubwayo, Uwamahoro & Ndayambaje (2020), who, via RTOP results, found that teachers do not promote prediction among students. The inquiry is associated with science, a complex activity involving observation, questioning, examining various sources of information to reveal what is already known in the light of experimental evidence, investigating inferences by gathering/analyze/and interpret data, proposing answers and explanations, and communicating the outcome (Mugabo, 2012).

4. Discussion of Practical Implication

Teacher 1 planned the lessons from the KUC "by the end of this unit; the learner should be able to explain the properties of lenses and image formation by lenses" from S4.

Teacher 1 fully used group formulation in all LPs, where he emphasized on mixing girls and boys as a criterion of the group formulation. This may be caused by the gender inclusion expected in the 8 CCIs (REB, 2015b). This inclusion is subtle. However, teachers should go beyond this and ensure that boys and girls have the same learning rights. Contrary wise, Teacher 4 mentioned it. He wrote: "gender balance: boys and girls are given equal responsibilities." Teachers should also emphasize the inclusion of able students and struggling students to employ a specific ALT purposively (refer to Appendix B for more detail). In presenting the results, the teacher only uses the group leader. This act may discourage other students and pressure the group leader. It is better to randomly select the presenter so that everyone is ready to work as none knows who will present the group findings. In describing the competences to be accommodated, the teacher usually mentions: "skills in organizing scattered data to develop systematic, observation, and detailed presentation"; however, in the teacher or students' activity, there was not appearance of any doing an experiment, observing nature or inquiry. He also wrote that "skills in report presentation, for example, in Microsoft PowerPoint" while in the teacher or student activities, it appears presenting on the blackboard. An LP serves as a map guiding the teacher during the teaching process (Ndihokubwayo et al. 2020). However, it seems it is a formality. For instance, in the "learning materials" place, the teacher mentions some materials such as a calculator, internet connection. However, he does not describe how they will be used in the main lesson (teacher and learner activities). Straessle (2014) found that many teachers use written lesson plans but they do not often refer to them during class delivery. Therefore, teachers need to take LPs as their road map toward effective lesson delivery. Teachers should write their lesson plan with full consideration. They should revise it to check everything is in place. Refer to a model lesson plan in Appendix C3 as a standardized and full lesson plan.

Teacher 2 planned the lessons from the KUC "by the end of this unit, the learner should be able to explain the properties of lenses and image formation by lenses" from S4, and "the learner should be able to analyze the nature of light" from S5.

Teacher 2 outlined the activities to be done by students and teachers. She took the students into experiments and discussion of results through group work. She said the teacher should do the first activity of the experiment while students do the next step. However, this is good; however, this is good; she may be sure that students cannot do even the first step if the teacher guides them skillfully. She outlined the GCs and CCIs without explaining how they will be catered and achieved. Thus, their role according to each and specific activity is lost. Teacher 2 differs from Teacher 1 in the way that she planned for the experiment, although she did not provide the name of an experiment to be done or specifies its steps. The teacher considered writing a lab report as an assessment during the Conclusion of the lesson. The study of Amanda G. Sawyer showed that teachers vary in the choices of resources for lesson planning due to their different experiences.

Teacher 3 planned the lessons from the KUC "by the end of this unit; the learner should be able to explain the properties of lenses and image formation by lenses" and "by the end of this unit, the learner should be able to analyze the function of the simple and compound microscope" from S4.

In the lesson on Measuring the focal length of the convex lens, the teacher set the IO well (refer to Appendix B for more detail). For instance, he wrote, "given lenses and other necessary apparatus, learners should be able to determine the focal length of a convex lens effectively." This is in line with the Straessle (2014) study, where teachers did not differentiate among the components of lesson planning, although they care about clear learning objectives than other components.

Most of the time, the teacher introduces before learners are assigned to the group works. He then emphasizes that students should follow his explanation actively. In some of the LPs, the teacher described the SEN though he did not address them in the lesson development. For instance, he wrote, "some students are quick while others are slow in learning." Somewhere he even specifies the number "five students have difficulties in understanding English" or "five students have disruptive behavior." Always the teacher summarizes or concludes the lesson, and students take notes.

Teacher 4 planned the lessons from the KUC "by the end of this unit; the learner should be able to analyze the nature of light" from S5.

Most of all the teachers used a particular ALT without purpose. For instance, Teacher 4 started by assigning students into groups. The use of such group work should take a source, for example, after assigning students with individual work, and the teacher notices difficulties among students to perform the given activity or exercise. Most of the teachers ask questions in the Conclusion and expect students to respond to those questions. However, these questions are not mentioned. These questions or exercises should be different from what was discussed in the lesson to avoid memorization and promote thinking. Thus, students should use what was learned to answer questions or perform exercises and not copy what they learned. This will increase their critical thinking as they achieved competence, and the lesson will be viewed at a wide-angle (to be used in various contexts). Our results show that teachers do not plan for a significant assignment that reflects students' context and the use of what was learned clearly. The Straessle (2014) study revealed that when creating assignments, teachers use real-world connections significantly more frequently than any other facet. This real-world context should be reflected when teachers emphasize allowing students to connect themselves and what they learn to their real-life situations. Moreover, this is well outlined and recommended in the syllabus (REB, 2015a) daily use.

Teacher 4 planned to request students to interpret their results. This is very important in promoting critical thinking. It alerts students that observation or experimentation is not a standalone lesson objective; instead, a further inference of the results is necessary to get the meaning of what they learn. Most of the teachers care about critical thinking as a GC. Only teacher 4 emphasizes long-life learning. For instance, "students will develop long-life learning by taking the initiative to update knowledge and skills with minimum external support." This is very crucial to motivate such senior five students to look further in their future. It may help them to plan for their future studies and career.

Teacher 4 describes the "DTLA" well. For instance, in the lesson of "measuring the Plank's constant," he wrote the DTLA: "using an electronic circuit containing a LED power supply, digital millimeter, and a digital voltmeter, learners with the help of the teacher describe how to measure Plank's constant." This may guide anyone who reads the LP (for instance, before observing class) on what will be done during the teaching and learning process. Teacher 4 encourages the students to make a prediction. This helps students to observe and think by relating their prerequisite knowledge to a new observation. Teachers outline what will be done in the lesson but do not describe what and how they will be done. In the case of teaching activity, if, for example, the teacher is not available to teach the lesson, Deputy Of Studies will not have an opportunity to assign another teacher to teach such lessons as it is not well and fully elaborated.

Teacher 5 planned the lessons from the KUC "by the end of this unit; the learner should be able to explain the properties of lenses and image formation by lenses" from S4 and "by the end of this unit, the learner should be able to analyze the nature of light" from S5.

Teacher 5 planed to provide short notes to students and give time to copy notes. He is brief in planning all the LP steps, even in writing the KUC in full. Thus, he shortened the KUC. He wrote, "explain the properties of lenses."

Most of the teachers start the introduction section by asking students questions about the previous lesson. None of the teachers uses the LP format segmenting the development section into discovery activities, presentation learners' findings production, exploitation findings production, and the conclusion section into conclusion/summary and assessment/homework. This shows why all LPs show a poor description of activities to be done during the teaching and learning process. Thus, if the teacher fills the LP format by planning for these components of development and conclusion sections, the LP would be clearer and directive to any other teacher or any classroom observer.

5. Conclusion and limitations

In this study, LPAP findings showed that physics teachers' lesson plans do not reflect well on the competence-based curriculum. Teachers do not follow the REB LP format, do not cater to slow learners, and are reluctant to use effective active learning techniques. There is no need to limit teachers on which lesson plan format to use; however, REB needs to guide them effectively during in-service teacher training. Probably, what is essential is not the format, rather what to consider while planning a lesson. Our findings show that the LPEF analysis indicates that teachers do not use higher levels of the cognitive and affective domains. Teachers do not consider following inquiry techniques too. Data from the lesson plan analysis should be supplemented by classroom observation. Although reviewing lesson plans added little to the accuracy of rating a teacher's performance, however, this is a reasonable prediction that if a good preparation were considered, the reformed teaching would also increase. The limitations of our study lie on small sample disabling us to generalize our results. Therefore, further studies should focus on the scheme of work as an important pedagogical document and check its alignment to the lesson plan with a sounding teachers' sample as well as lesson delivery.

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Appendices

Appendix A: Pedagogical document reviewed

We have requested LPs from 11 teachers. We analyzed 32 lesson plans from five teachers, where 24 were from S4 while eight were from S5. Fourteen LPs were single lessons of 40 minutes period, 10 were double periods of 80 minutes each, while 8 had triple periods of 120 minutes each.

Table A1: Lesson Plans collected alongside the optics content

no	Topic	Date	Min
S4 lesson plans			
1	Magnification of the lens, Power of the lens, and exercises on formula of the lens	6/2/2019	40
2	Determination of the focal length of the lens	8/2/2019	40
3	Refraction through a prism (deviation of light by a prism)	15/2/2019	40
4	The angle of minimum deviation and determination of the refractive index	16/2/2019	40
5	Summary (Exercises) of all topics in this unit by giving exercises	21/2/2098	40

1	Minimum deviation angles in prisms	6/1/2019	40
2	Physical features and types of thin lenses	21/1/2019	40
3	The image formed by a thin lens	23/1/2019	40
4	The formula of a thin lens	28/1/2019	40
5	Refraction of light through a prism	29/1/2019	40
6	Angles of minimum deviation and refractive index	30/1/2019	40
7	Deviation of light by a small angle of the prism	4/2/2019	40
8	Refractive index of the material	5/2/2019	40
1	Thin lens	25/1/2019	80
1	Thin lens equation	22/1/2019	120
2	Measurement of the focal length of a convex lens	29/1/2019	120
3	Defects of lenses and their correction. Refraction through prism	5/2/2019	120
4	Refraction through a prism, a term associated with refraction through a prism	7/2/2019	120
5	Deviation of light rays by a glass prism. The angle of minimum deviation and determination of the refractive index	12/02/2019	120
6	The angle of minimum deviation of a glass prism	14/2/2019	120
7	Lens maker's equation (Full lens equation)	19/2/2019	120
8	Definition of an optical instrument and angular magnification, the human eye, and visual angle	25/2/2019	80
9	Formation of the image by a lens camera Slide projector	28/2/2019	120
10	The terrestrial telescope, Galilean and reflecting telescope	11/3/2019	80
S5 lesson plans			
1	Compton effect and photon interaction	25/1/2019	40
1	Wave and particle nature of light	18/1/2019	80
1	The measure of Planck's constant	22/1/2019	80
2	Representation, characteristics, and properties of sounds waves	28/1/2019	80
3	Blackbody radiation	31/1/2019	80
4	Guidelines for doing physics practical	31/1/2019	80
5	Compton effect and photon interaction	7/2/2019	80
6	Electron microscope	12/2/2019	80

Appendix B: Lack of IO and Presence of TR, FA, and ALT among reviewed LPs

In this appendix, we presented what IO components lacked in LPs written by five teachers (Table B1) and the presence of TR, FA, and ALT among five teachers' LPs (Table B2).

Table B1 Lack of IO

	Condition	Who	Action	Content	Standard/criterion
T1	5				4
T2	5				10
T3	1				
T4	1				1
T5	2				2

Table B2 The presence of TR, FA, and ALT

	TR	**FA**	**ALT**
T1	Pen, Pencil (1)	Questioning (5)	Group discussion (4)
	Pen, Pencil, Prism (2)	Group activities (2)	Group activities (2)
	Pen, Pencil, Prism, Calculator (2)		
T2	Prism, pens, paper (3)	Questioning (9)	Lab activities (1)
	Ruler, textbooks (1)	Group activities (8)	Discussion (2)
	Charts (2)		Group activities (9)
	Blackboard, Chalk Board (1)		Presentation (2)
			Demonstration (1)
			Providing examples (1)
T3	Chalks, notebooks, figures	Questioning (5)	Group activities (9)
	Chalks, notebooks, figures, experiment protocol	Group activities (5)	Presentation (3)
	Chalks, notebooks, pens.	Exercises, quiz (4)	
	Chalks, notebooks, pens, prism		
	Calculator, notebooks, pens, Equilateral Glass Prism		
	Calculator, notebooks, pens.		
	Chart, simple microscope, Calculator, notebooks, pens.		
	Lens Camera, slide projector, pens (2)		
T4	String	Questioning (6)	Group discussion (4)
	White and black clothes, sunlight (2)		Presentation (2)
	Marbles		Group activities (1)
	Simple magnifying glasses		Brainstorming (3)
			Roleplay (4)
			Note-taking (6)
T5		Questioning (2)	Group discussion (2)
			Presentation (1)
			Roleplay (1)
			Note-taking (2)

Appendix C: Model Lesson Plan

Preparation for class may take many forms. Notably, there are 2 phases before a teacher enters the class and the other two after he/she enters the class. These are pre-plan, lesson planning, and lesson delivery, and teacher assessment (REB, 2017). The pre-plan is when a teacher thinks about what he/she will do, what is needed, which method, materials, or teaching aids he/she will use, how he/she will cater to students, manage class, including varieties among students. After pre-planning mentally, the teacher needs to plan on the paper. This is the lesson planning phase.

To write the model Physics LP, we have chosen to only focus on one topic (Determination of the refractive index of the prism) and planned to be taught in 2 periods (see Table C1). We consulted the syllabus (Rwanda Education Board, 2015a, pp. 23-24), student textbook (Birindwa & Atwebembeire, 2016b, pp. 49-58), and the teacher's guide (Birindwa & Atwebembeire, 2016, pp. 1-2 and 18-20).

Table C1 Scheme of work for Unit 1 Thin lenses

s/n	Syllabus	Student's book	Teacher's guide (no of periods)
1	Characteristics of lenses	Characteristics of lenses (pp. 4-6) Terms used in lenses (pp. 7-11)	Types of lenses and their characteristics (2)
2	Types of lenses: converging (double convex, plan convex, convex meniscus) and diverging (double concave, plano-concave, concave meniscus)		
3	Refraction of light through lenses.	Refraction of light through lenses (p. 12) Properties of images formed by lenses (pp. 13-16)	Terms used in lenses, refraction of light by lenses, Images formed by lenses (2)
4	Ray drawing and properties of images formed by lenses for an object located at different positions.	Ray diagrams and properties of images formed by lenses (pp. 16-19) Ray diagrams for a convex lens (pp. 20-23)	Ray diagrams and images formed by lenses (2)
5	Graphical determination of the focal length of lenses	Accurate construction of ray diagrams (pp. 23-24)	Graphical determination of the focal length of a convex Lens (2)
6	Thin lens equation, Power of lens, magnification, and sign convention.	The thin lens formula (pp. 24-25) The sign convention (p. 25) Derivation of the lens formula (pp. 26-29) Magnification (pp. 29-30) Applications of the lens formula (pp. 30-33) Power of the lens (p. 33) Determination of the focal length of the lens (pp. 34-37)	Thin lens formula (equation), the sign convention (2) Magnification, Power of the lens (2) Determination of focal length of a concave lens (2)

7	Lens combination and effective focal length	Combination of lenses (pp. 37-40) Defects of lenses and their corrections (pp. 40-42)	Combination of lenses, and effective focal length of the lens combination (2)
8	Derivation of lenses formulae		
9	Defects and correction of lenses		Defects of lenses and their corrections, refraction through glass prisms (Introduction and terms associated with refraction through the prisms) (2)
10	Applications of combined lenses		
11	Refraction through prisms	Refraction through prisms (pp. 43-44)	
12	Terms associated with the refraction of passing through a prism	Terms associated with refraction through a prism (pp. 44-45) General formulae for the prism (pp. 45-49)	
13	Deviation of light rays by a glass prism.	Deviation of light by a prism (pp. 49-51)	Determination of refractive index of the prism; Deviation of light by the prism, Minimum deviation, Determination of refractive index of a material of a glass prism using minimum deviation (2)
14	The angle of minimum deviation and the determination of the refractive index of a prism	The angle of minimum deviation and determination of refractive index n of a material of the prism (pp. 51-53) The angle of minimum deviation and the refractive index n of the material (pp. 53-54) Deviation of light by a small angle prism (pp. 54-57) Determination of refractive index of a material of a prism (pp. 57-58)	
15	Dispersion of light by a prism	Dispersion of light by a prism (pp. 58-59)	Dispersion of light, Applications of total internal reflection by a prism (2)
16	Applications of total internal reflection of light by a prism	Applications of total internal reflection of light by a prism (pp. 59-60) Use of prisms in periscopes (pp. 60-61)	
17	Problem-solving related to combined thin lenses and refraction of light	Exercises (pp. 62-68)	Problem-solving related to combined thin lenses and refraction of light (2)

The unit of thin lenses comprises 17 topics (REB, 2015a, pp. 23-24) to be completed in 24 periods (one period is 40 minutes). Six topics are related to prism—refraction through prisms, terms associated with the refraction of passing through a prism, deviation of light rays by a glass prism, angle of minimum deviation and the determination of the refractive index of a prism, dispersion of light by a prism, and applications of total internal reflection of light by a prism.

Table C2 is the sample lesson plan. This is one LP (Table D1) from sampled 32 LPs. It is the one we referred to during preparing the model physics lesson plan (Table C3).

Table C2: Sample LP

LESSON PLAN

School Name: [redacted] Teacher's name: [redacted]

Term	Date	Subject	Class	Unit N°	Lesson N°	Duration	Class size
1	12/02/2019	Physics	S4PCB	1	… of ….	120min	23

Type of Special Educational Needs to be catered for in this lesson and number of learners in each category	None
Unit title	Thin lenses
Key Unit Competence	By the end of this unit learner should be able to explain the properties of lens and image formation
Title of the lesson	Deviation of light rays by a glass prism: Angle of minimum deviation and determination of refractive index
Instructional Objective	Given enough explanation learner should be able to explain the formula and minimum deviation produced by a prism and its relation with the refractive index
Plan for this Class (location: in / outside)	In Classroom
Learning Materials (for all learners)	Glass prism, pens, calculator and notebooks
References	Physics for Rwanda secondary schools book

Timing for each step	Description of teaching and learning activity: Description of angle of minimum deviation produced by a prism and determination of refractive index		Generic competences and Cross cutting issues to be addressed + a short explanation
	Teacher activities	Learner activities	
Introduction 20min	ASK questions about the previous lesson	Answer questions and ask question for any confusion	G.C. Communication skills will be developed through answering question
Development of the lesson 80min	Describe briefly refraction of light through a prism, of minimum deviation and the relationship with refractive index	Follow actively and participate in group discussion to solve example in group and on the chalk board. ASK and answer questions for any confusion raised. Note the summary on the notebook	*cooperation and cooperative will be developed. critical thinking and problem solving will be developed. creative and innovation through derivations of formula
Conclusion 20min	Give the exercises	solve the exercises on chalk book and notebook	critical thinking through exercise solving
Teacher self-evaluation	taught		

Note that the lesson plan we drafted is in the format recommended by the REB. We followed their format, but the content was prepared as an example by ourselves to support the LP under Table C2. So, the mistakes or misinformation that may be brought by our content has no way to be attributed to REB or teacher's LP under Table C2. However, we have validated it to the extent it can serve as a model lesson plan to be consulted by any physics teacher for proper planning. Our LP draft was shared with seven people. These were three URCE assistant physics lecturers (among them one teach teaching methods in addition to physics), one consultant who worked for the SIIQS[3] project, and three master students at ACEITLMS/URCE who were physics teachers in secondary schools before 2019. After receiving their validation reports (five reports from five people who responded to our request), we have considered their suggestions and input to enrich our LP draft and provide the current model LP (see Table C3).

[3] SIIQS refers to the Project for Supporting Institutionalizing and Improving the Quality of SBI (School-Based In-service Teacher Training) Activity. This project was piloted jointly by Rwanda Education Board (REB) and Japan International Cooperation Agency (JICA) from 2017 to 2019

Table C3: Model lesson plan

School name: ………X……………………….. **Teacher's name:** …………X……...

<table>
<tr><th>Term</th><th>Date</th><th>Subject</th><th>Class</th><th>Unit Nº</th><th>Lesson Nº</th><th>Duration</th><th>Class size</th></tr>
<tr><td>I</td><td>12 February 2019</td><td>Physics</td><td>Senior 4 PCB</td><td>1</td><td>10 of 12</td><td>80 Minutes</td><td>45</td></tr>
<tr><td colspan="4">Type of Special Educational Needs to be catered for in this lesson and number of learners in each category</td><td colspan="4">One student has visual impairment (short-sightedness) while ten students are slow to understand physics concepts together with the other seven students fear mathematical formulae</td></tr>
<tr><td>Unit title</td><td colspan="7">Thin lenses</td></tr>
<tr><td>Key Unit Competence</td><td colspan="7">By the end of this unit, the learner should be able to explain the properties of lenses and image formation by lenses</td></tr>
<tr><td>Title of the lesson</td><td colspan="7">Determination of refractive index of the Prism; Deviation of light by the Prism, Minimum deviation, Determination of refractive index of a material of a glass prism using minimum deviation</td></tr>
<tr><td>Instructional Objective</td><td colspan="7">Through experiments using materials such as glass prism of refracting angle 60^o, a sheet of paper, soft board, pins, and pencils, ruler, and protractor; through a series of exercises; learners should be able to:
• determine the refractive index of a material of a prism correctly.
• measure the angle of deviation d accurately
• plot a graph of deviation d against the angle of incidence accurately
• clearly explain the deviation formula and minimum deviation produced by a prism and its relationship with the refractive index
• determine the refractive index of a material of a glass prism using the minimum deviation formula easily.</td></tr>
<tr><td>Plan for this Class (location: in / outside)</td><td colspan="7">This lesson will be conducted inside the classroom</td></tr>
<tr><td>Learning Materials</td><td colspan="7" rowspan="2">Glass prism, pins, white papers, soft board, pencils, ruler, protractor, calculators, notebooks</td></tr>
<tr><td>(for all learners)</td></tr>
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References	Physics for Rwandan secondary schools Learner's Book 4, Fountain Publishers		
Timing for each step	**Description of teaching/learning activities**		
	In groups, students perform experiments to determine the refractive index of the prism. The teacher provides materials, gives instructions, and guides students while students are busy working towards lesson objectives.		**Generic competences** and **Cross-cutting issues** to be addressed **+** **a short explanation Teacher's activities**
	Teacher's activities	**Learner's activities**	
1. Introduction (10 min)	Ask questions about the previous lesson: *-Describe a prism as an apparatus that refracts light* *-Write and interpret the Snell's law and the angle of the prism* Guide students in answering questions and clarifying for better conceptual understanding. Identify students with poor understanding (slow learners). Make sure everyone understands before the next lesson; otherwise, consider them in the next lesson. Make sure students with short-sightedness are sitting in front.	Answer to asked questions *-In optics, a prism is a transparent material like glass or plastic that refracts light. At least two of the flat surfaces must have an angle of less than 90^o between them. The exact angle between the surfaces depends on the application.* *-Note that given i_1, r_1, and i_2, r_2 as angles of incidence and refraction at F and G as shown and n is the prism refractive index, then Snell's law holds. That is; Sin $i_1 = n \sin r_1$, and Sin $i_2 = n \sin r_2$.* *Angle A: This is called the refracting angle or angle of the prism. It is the angle between the inclined surfaces of the prism. $r_1 + r_2 = A$.*	GC: Communication skills will be developed through answering questions CC: Inclusive Education will be catered for throughout the lesson

2. Development of the lesson (65 min) **2.1 discovery activities (20 min)**	Form groups (seven groups of 6-7 students) by considering a mixture of both boys and girls, smart and slow learners. Give instructions on what they are going to do (experiment). Assign different experiment tasks to different groups of students in order to keep time and call attention. Ask students to follow the procedures and record findings in their notebooks. *Remind them that they have different tasks and be ready to teach their colleagues what every group did and found.* Guide each group to achieve expected results and monitor the experiment procedure. Note down the difficulties that groups face and individuals' capabilities to learn which groups will present in the next session.	Follow instructions and form groups as requested. Participate actively in groups by helping each other to perform experiments and following the procedure referred to in textbooks. Experiment 1 (to be done by group 1, 4, and 7) *Determination of refractive index of a material of a prism (activity 32, p. 57 student's book)* Experiment 2 (to be done by group 2 and 5) *Deviation of light by the prism (activity 30, p. 50 student's book)* Experiment 3 (to be done by group 3 and 6) *Minimum deviation (activity 31, p. 51 student's book)* Ask for guidance and record data on the notebook.	GC: Cooperation will be developed through working together performing experiment GC: Interpersonal relations and life skills will be developed by supporting each other perform experiment

2.2 presentation learners' findings production (15 min)	Make sure students respect the time and spare time for them to share their findings. *Depending on the teacher's notes (during monitoring experimentation),* assign one of the groups who performed experiment 1 to present on what they did and found. It is better to allow the group that got difficulties in order to raise discussion in the next session. Let the group that faced more challenges take the first floor to present and turn those challenges into an opportunity to better understand concepts.	Group 1 or 4 or 7 shares what they did related to experiment 1 in front of the class Group 2 or 5 shares what they did related to experiment 2 in front of the class Group 3 or 6 shares what they did related to experiment 3 in front of the class Other students follow actively and participate in discussions by asking for clarification.	GC: Communication skills will be developed during students presentation GC: Creativity and innovation will be developed through generating the ideas in case of being challenged
2.3 exploitation findings production (20 min)	Start the discussion by motivating the rest of the class to challenge the presenters. Guide discussion of students. Give an activity for all the groups. This will make students use what they found in the experimentation. *Activity: Determination of refractive index of a material of a glass prism using minimum deviation by working out exercises as group work.*	Ask clarification, and others respond Discuss the presented findings. Derive the relation between minimum deviation and the refractive index of the material: $n = Sin\frac{(Dmin+A)}{2}/Sin\frac{A}{2}$	GC: Cooperation and Interpersonal relations and life skills will be developed through discussion and challenging each other GC: Critical thinking and problem solving will be developed through the derivation of formula and solving exercises

	Guide the learners to derive the relation between minimum deviation and the refractive index of the material by specifically encouraging students that fear mathematical formulae. *It is better the teacher presents at least two diagrams of the prism, the first one in the normal way and the second one at minimum deviation so that they explore the difference between them and the students can measure the angles of those two prisms and then find the conditions for minimum deviation in addition to that the teacher must help the students to be familiar in the derivation of 4 formulas of prism before attacking minimum deviation.* Monitor how they use what was learned to adapt to a new situation in solving exercises. *If possible, the teacher must clarify the presentation of students by adding scientific information. He/she can show a video to the students for good exploration and clarification.*	Derive the formulas and use them in the exercises on notebooks and a chalkboard *(work through exercise on page 60 in student's book).*	GC: Lifelong learning will be developed through exploiting other opportunities available to better improve the knowledge as well as skills

2.4 conclusion/ summary (10 min)	Call for volunteer students to sum up what was learned. *A better way is to call some students whom you found had some challenges.* *Another way is to ask one student from groups that did, let say, experiment 1 to talk about what he/she learned from the work done by students who did experiment 2 or 3.* *Another better way is to ask everyone to write a summary of today's lesson.* Help students contextual and appreciate the competences gained and skills got in today's lesson. Motivate learners to record notes.	Groups evaluate each other Students share what they learned new in the lesson Propose what to do for a better understanding. Share the importance of today's lesson. Share how to apply what they learned in everyday life. Record notes on the individual notebook.	GC: Interpersonal relations and life skills will be developed through challenging each other; therefore, this will promote the Development of the higher-order thinking skills GC: Lifelong learning will be developed via contextualizing the learned concepts
3. assessment /homework (5 min)	Assign homework as an individual work.	Record the homework in an individual notebook.	
Teacher self-evaluation	The lesson was well done; about ten students still have difficulties in mathematical formulae; before the next lesson (lesson 11: Dispersion of light), I will make corrections of homework by engaging them during the first 15 minutes.		