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RESEARCH PAPER

The Identification of Criteria for a Lab Report Scoring Checklist to Assess Practical Skills Indirectly in an Undergraduate Optics Course

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Abstract

Practical skills are essential skills in physics courses, especially in the laboratory setting. Therefore, these skills must be appropriately assessed to ensure undergraduates' readiness in the working environment with adequate skills. This paper aims to identify the criteria for a scoring checklist to assess practical skills indirectly in an undergraduate optics course. This study employed a Developmental Research Type 1 design using qualitative and quantitative methods. A scoring checklist is constructed using the ADDIE instructional model of five main phases: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. In this paper, the researcher describes the first three phases of producing the lab report scoring checklist to assess practical skills indirectly among undergraduates in an optics course. In conclusion, a set of 47 criteria to assess practical skills indirectly among undergraduates in an optics course has been identified and is ready for the next stages of analysis. The process of identifying suitable criteria can be replicated where applicable to another course to identify or generate criteria that fit the study context.

Keywords: development, assessment tool, indirect assessment, practical skills,

INTRODUCTION

Outcome-based education is an approach to education in which decisions about the curriculum are driven by a set of learning outcomes that the students should exhibit at the end of a course (Davis, 2003). Students must achieve specific learning outcomes to align with the OBE concept. The outcomes must be achievable, measurable, and aligned with the three main domains:(1) cognitive, (2) affective, and (3) psychomotor of Bloom's Taxonomy (Rao, 2020). Many countries address the learning outcomes corresponding to the global education concept of outcome-based education. In Malaysia, the Malaysian Qualification Agency (MQA) is an agency responsible for implementing the Malaysian Qualifications Framework (MQF), accrediting higher education programs and qualifications, supervising and regulating higher education providers' quality and standards, establishing and maintaining the Malaysian Qualifications Register and providing for related matters (Malaysian Qualifications Agency, 2017). One of the main goals of the MQA is to address the learning outcomes for all of the programs that Malaysian higher education institutions provide.

Learning outcomes are statements of the knowledge, skills, and abilities that individual students should possess and can demonstrate upon completing a learning experience or sequence of learning experiences. In this study, the researcher focuses on a Malaysian university that will be referred to as the university of interest (UOI). In the UOI, lecturers and students will be provided with a 'Course Pro Forma' (PF) for every offered course. It consists of course info, synopsis, names of academic staff, semester and year offered, pre-requisite, course learning outcome (CLO), mapping of the course to the program learning outcomes, transferable skill, distribution of student learning time, special requirements, reference, additional information, and coordinator verification. The learning outcomes stated in the PF are based on the learning outcomes categorized into five clusters by the MQA. There are five clusters of learning outcomes: Knowledge and Understanding, Cognitive Skills, Functional Works Skills, Personal and Entrepreneurial skills, and Ethics and Professionalism (Malaysian Qualifications Agency, 2017). All CLOs in an education program at the undergraduate level must cover these clusters to comply with the Malaysian education program standard.

As for the undergraduate optics course (referred to as UOC in this paper) in UOI, the CLOs are developed based on the three learning domains; cognitive, affective, and psychomotor. The psychomotor domain is often linked with practical skills. For example, one item of the CLO requires the students to perform laboratory exercises and report writings. The item was categorized as a level 3 psychomotor domain (code P3), which is 'Guided Response' based on the Simpson (1971) behaviours levels. Therefore, practical skills are important criteria in OBE as it helps students develop their psychomotor skills. Practical skills are essential for students in science-based courses and are mostly developed in the laboratory environment. Typically, practical skills in the laboratory involve handling and manipulating materials and apparatus in a scientific investigation (Abrahams & Reiss, 2015; Fadzil & Saat, 2018; Hancock & Hollamby, 2020). Practical skills in the laboratory are critical among undergraduates in most practical science courses like chemistry, medical science, and engineering (Achumba et al., 2013; Kolivand et al., 2020; Reid & Shah, 2007; Zhang et al., 2020). In addition, practical skills are key components of undergraduates' readiness in the working environment. Failure to master the skills at the beginning of a degree course may impair performance in later modules (Hancock & Hollamby, 2020). Therefore, it is important to assess these skills properly to ensure the students can achieve the intended CLO.

According to Abrahams, Reiss and Sharpe (2013), practical skills can be evaluated directly or indirectly in science and other courses. The direct method is the Direct Assessment of Practical Skills (DAPS), which refers to any assessment that demands students to show a specific or generic skill by manipulating real items in a way that may be used to measure their degree of competence in that skill. On the other hand, Indirect Assessment of Practical Skills (IAPS) is any method of assessment in which a student's level of ability, in terms of a specific or generic skill, is inferred from their data and/or reports of practical work they completed. Although both assessments are different, they can be a benefit if used in a suitable context. In UOC, the class size is large (40 to 60 students per lecture group), and the laboratory session time provided is only six hours per semester. Given the nature of the demanding lecturers' teaching load, large class size, and limited laboratory session time, applying the IAPS method by assessing students’ lab reports is the most suitable approach for this study context. The course lecturer has developed an assessment tool to assess the students’ lab reports. However, even though the current assessment tool has been used for several semesters, it is not backed up with solid and extensive academic literature and systematic production.

Therefore, developing a valid and reliable scoring tool to assess students' lab reports is a must to overcome these problems. This study aims to develop a scoring tool to assess students' practical skills indirectly. This paper will answer the following research question: What are the suitable criteria in a lab report scoring checklist to assess practical skills indirectly among undergraduates in an optics course?

METHODOLOGY

This study employed a Developmental Research Type 1 design using both qualitative and quantitative methods. A scoring checklist is constructed using the ADDIE development model with five main phases: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. This study will explicitly focus on the analysis, design, and development phases only to answer the research question: What are the suitable criteria in a lab report scoring checklist to assess practical skills indirectly among undergraduates in an optics course?

Analysis

Developing the scoring checklist required detailed processes to ensure it is usable in the right context. The process starts from the Analysis phase. In this phase, the researcher conducts a needs analysis to obtain the needs of this study. The needs analysis involves two types of analyses: (1) semi-structured interviews and (2) document analysis (Table 1). This study started with interviewing four physics lecturers involved in the laboratory environment. The interview consists of open-ended questions of a semi-structured interview, allowing the researcher not strictly to follow a formalized list of questions. Instead, the questions are guided according to the research objectives. The interview is done by phone due to movement restrictions in the pandemic COVID-19 situation. The interviews were conducted from April until May 2021, considering the lecturers' different free time. The interviews were within Semester 2 Session 2020/2021 in the UOI academic calendar.

Table 1. Needs analysis time frame

Date/Task	Semester 2 (2020/2021)				
	Apr-21	May-21	June-21	July-21	August-21
Lecturers' Interview (Semi-structured)					
Lab Report Marking (Document Analysis)					
Students' Interview (Semi-structured)					

The lecturers' interview questions were mainly about their current laboratory assessment and their desired assessment tool criteria. The interviews were quite short (about three to five minutes each) since they were unfamiliar with different assessment tools. As summarized in Table 2, the number of students per lecture group is quite consistent among the three courses for every semester except for Undergraduate Optics, referred to as UOC in this paper. All interviewed lecturers used the same approach to assess the practical skills in the laboratory sessions: lab report marking. The practical skills were assessed based on the lab report prepared by students in groups. However, the assessment tool used is different for the undergraduate optics course compared to the other three courses, which used the rubric type. The UOC lecturer stated that he uses the hybrid type of assessment tool because it is simple and quick to use for assessing large classes. That statement leads to the terminal question: What are the criteria of the desired assessment tool that the lecturers wish to use in their laboratory assessment? The answers are the same. They prefer a simple tool to reduce the current teaching loads. In addition, the UOC lecturer suggests a simple tool that can produce consistent grades among different markers since the same course might be handled by different lecturers. The college optics lecturer also suggests an automated scoring tool as it reduces the human effort to do the marking.

Table 2. Summary of interview with lecturers

Course (level)	Number of students per lecture in a group	Current assessment tool	Approach	Desired tool criteria
Thermodynamic (Undergraduate)	25 to 30	Rubric	Lab report marking	Simple, easy to use
Optics (College)	30 to 35	Rubric	Lab report marking	Simple, automated scoring tool
Electromagnetism (Undergraduate)	30 to 40	Rubric	Lab report marking	Simple
Optics (Undergraduate) *referred to as UOC in this paper*	40 to 60	Hybrid tool (checklist + rubric)	Lab report marking	Simple and clear, produce consistent scores among different markers

After reviewing the feedback from the interview, the researcher chooses to conduct the study in an undergraduate optics course as the class size is the largest. The desired assessment tool should be convenient for assessing lab reports in large class sizes. A document analysis was performed by marking all the lab reports for assigned experiments in that course to understand the assessment environment in the course. The marking process is a part of the diagnostic analysis to obtain the trend of both the student work and the marking scheme. Every student was allowed to form a subgroup with their classmates. Every subgroup consists of three to four students working together throughout the semester. The course sets out three experiments for every semester, with 36 subgroups across all the lecture groups. Therefore, the researcher marked a total of 108 lab reports for all groups and experiments to experience and immerse in the assessment process. The marking process was conducted in June 2021 for a week due to the current laboratory system of one-shot marking for the three experiments.

From the researcher's marking experience, the current hybrid tool (Figure 1) is quite simple to use in the marking process. However, this hybrid seems to have a problem since some items are vague. For example, the data analysis item provides six marks, but the indicator for the marks is not stated. A standard rubric usually displays a range of achievement levels with specific indicators and scores for every level. Without the indicators, the researcher tends to lose the guide on the marking process, which will slow down the work. In addition, several students also contact the researcher to discuss the reason for their marks deduction. The discussions usually last for 10 to 20 minutes because of the vague items. Although the researcher has stated the reasons for deduction in the lab reports when returning to them, the feedback seems not enough and does not satisfy the students. Therefore, the researcher interviews some students to obtain their views and comments regarding the laboratory assessment.

Six UOC students of Semester 2 (2020/2021) are selected randomly to participate in the interview. To avoid any worries that the course lecturer will have a problem with their replies, the researcher has stated that all students' information will be kept confidential from any parties. The interview is conducted for 10 to 15 minutes for every student. The interview questions are mainly about the students' satisfaction with the given marks, comments about the current UOC assessment tool, and their suggestions for laboratory assessment methods. For example, when asked about their preferred scoring tool across all courses they have taken in their program and the reasons, their responses are as listed in Table 3. These students preferred the optics hybrid checklist compared to tools that they had experienced in another course because it is straightforward, clear, simple, easy to understand, systematic, concise, indicates mistakes, thorough, and detailed.

Table 3. Students' responses to the preferred tool for laboratory assessment

Student	Preferred Tool	Reason	Verbatim
S1	UOC hybrid tool	Straightforward, clear, simple, easy to understand	*I give one example of a course that I have attended. The lecturer gave the students a scoring rubric on a scale of 1 to 5. The rubric is more details. However, I prefer the UOC assessment tool. The tool is more straightforward. It is clearer and simpler. I can understand it easily. For the UOC report, the students are already informed about the details and needs in the report. So, we can check the important things needed from the scoring sheet. In other courses, we are not provided with the scoring sheet. They only gave us a little information and instruction. So, we can identify the missing and needed parts using the scoring sheet**.*
S2	UOC hybrid tool	Systematic	*I prefer the UOC scoring because it is more systematic. So we can see the way of the lecturer's marking style.*
S3	UOC hybrid tool	Concise	*I feel like I am making a poster. I used to write a report, and it was about eight to ten pages. But when we write the UOC report, we concise the things that should be placed in the report.*
S4	UOC hybrid tool	Indicate mistakes	*UOC is better because we can know our mistakes.*
S5	UOC hybrid tool	Thorough	*The UOC course is quite unique because it is more thorough. It has a scoring sheet** and sort. I like the UOC style because the students can see what needs to be there. Furthermore, we can know the way of marking as well.*
S6	UOC hybrid tool	Detailed	*For the UOC reports, students already know in detail what needs to be in the report. So, we can check which part should be in the report from the scoresheet. In other courses, we were not given the scoresheet.*

*UOC is the abbreviation for the undergraduate optics course
**Scoring sheet is the current assessment tool used in the UOC for lab report criteria

When asked about any comments on the criteria in the current UOC tool (Figure 1), the students' replies are as stated in Table 4. Although the current tool is simple, as the students claimed, some criteria are not detailed enough. These criteria tend to confuse students and make them wonder why their mistakes are made. The researcher also faces the problem in the marking process from the marker's perspective

Please self-check on "Student checklist"

	Report check-list	Student checklist [/]	Instructor marks	
1	Maximum 6 pages	☒		**1**
2	Professional look:	-	-	**2**
	Consistent font and style	☒		
	Arrangement	☒		
3	Abstract Aim, Methodology & Key Finding)	-	-	**3**
	1) Aim 2) Methodology 3) Key Finding	☒ ☒ ☒		
4	Keywords	☒		**1**
5	Introduction	-	-	**2**
	1) Relevant theory 2) Connection between the theory and the experiment	☒ ☒		
6	Methodology	-	-	**2**
	1) Labeled figure 2) Correctly described the experiment	☒ ☒		
7	Data table	-	-	**4**
	1) Correct label using SI unit 2) Consistent decimal point 3) Logical data	☒ ☒ ☒		
8	Graph	-	-	**5**
	1) Title 2) Appropriate size 3) Axes label 4) Professional look 5) Correct fitting	☒ ☒ ☒ ☒ ☒		
9	Data analysis (Fulfill required task)	☒		**6**
10	Conclusion(s)	☒		**2**
11	Reflection	☒		**2**
		TOTAL		**30**
	EXACT COPY OF DATA AND REPORT AUTOMATIC ZERO MARK NO PLAGIARISME!			**0**

Figure 1. Current hybrid tool of the UOC

Table 4. Students' replies regarding the criteria in the current tool

Student	Criteria	Verbatim
S1	Conclusion	*I want to talk a bit about the conclusion. Because I am confused when writing it. When I remember the day at secondary school, there were many kinds of conclusions. Some are done in long sentences, and some are short. However, in the scoring sheet, it is not really specified and fixed. So, please check on the things needed in the conclusion. For example, it is a need to restate the objective? That is the first one, or is a need to show the final answer for the conclusion? Or, you can relate it to daily life. So the students can state the information clearly.*
S2	Correct label using SI unit	*We don't understand the SI units part. Because of those three experiments, our two experiments were mostly wrong with SI units. We don't know the reasons.*
S3	Introduction, connection between theory and experiment, graph	*I think my group members also agree with my suggestion. We lack understanding of 'introduction' and 'connection between theory and experiment.' Because when we have done everything and discussed what is wrong, we have corrected it. But when we get marks, the answer is still incorrect. Maybe in terms of other understandings, or the intent of the question is different.* *I like the scoring on the graph parts. Because the mark allocation is high, we can focus more on that part.*
S4	Data analysis, appropriate size of graph	**Researcher:** *For example, there is a 'data analysis' component (six marks). Do you know how to get those six marks?* **S4:** *I don't know.* **Researcher:** *'Appropriate size of graph' do you know what size is appropriate?* **S4:** *I don't know.*
S5	Introduction	*It is not that we don't really understand. Just a little confused. In the introduction part, where we relate the relevant theories needed. We were quite blurred on how to relate with relevant theories? Was the sentence structure correct when we wrote it? Because we felt that we had followed the report example* but still not valid in that part. So, we still get less encouraging feedback.*
S6	Data analysis	*I think the data analysis part because it is not clear. For example, does the data from our graph need to be explained? If yes, what is the thing that needs to be explained? I have given the details in the graph section: title, appropriate size, and more. But I don't know what to fill in the data analysis part.*

*Report example is the lab report for a random physics experiment that complies with all the scoring criteria.

The guided response is a psychomotor behaviour level where complex tasks are first attempted with the expert's guidance. Students are considered fulfilled the level by correctly performing the experiments and communicating their findings in a written form, which is a lab report. The gap between lecturer expectations using the scoring tool and student understanding of the scoring tool will lead to difficulties in task fulfilment. Therefore, from the needs analysis, the researcher can conclude the need to develop a valid and reliable scoring tool to assess practical skills in the laboratory environment, particularly in the case of UOC. A set of criteria should be identified for that purpose, which will be described in the following sections.

Design

The design phase involves gathering information for the initial criteria idea of the scoring tool. The first thing is the context. What are the things that the scoring tool will assess? UOC is offered every semester at UOI. The class size is limited to 40 per group, allowing students to form a maximum of ten subgroups in each group. The time provided for laboratory sessions every semester is only six hours covering three experiments by two hours for each experiment. Despite the lecturers' teaching load, it is challenging for them to assess students' practical skills directly. Recruiting a teaching assistant may be helpful but costly. Given the nature of the demanding lecturer's teaching load and cost issues, applying DAPS seems to give a lot of work for them as it requires more time to be implemented. Therefore, IAPS is more feasible for UOC by marking the students' lab reports.

The next thing is the assessment tool type. There are three types of assessment tools: (1) rubric, (2) rating scale, and (3) checklist. The rubric is very common in the education grading system as it displays a range of achievement levels with specific indicators and scores for every level (Hammerman, 2008). Rating scale and checklist types are very similar as the difference lie only in measurement modality. The rating scale asks for choices across a scale that does not describe performance, while the checklist asks for dichotomous choices (usually has/don't have or yes/no) for each criterion (Brookhart, 2018). After reviewing the tools, we developed a checklist because it is simple and dichotomous, which can increase the scoring transparency compared to tools where scorers select a score within a range of points (Killpack & Fulmer, 2018). Technically, the current tool for assessing the UOC lab reports is already a checklist type, even though it is a hybrid version. However, the current assessment tool is not backed up with solid and extensive academic literature and systematic production, even though it has been used for several semesters. Furthermore, the students' interview feedback informed that the current tool still needs work of improvement.

The developed checklist is dichotomous. Therefore, the marking system of the developed checklist is only one mark for the met criterion and zero marks for the criterion that did not meet. Since the nature of the checklist is the list of items required or to be done, it would be beneficial for students to have a column to check all the required criteria before submitting lab reports (Refer to Figure 2). Therefore, the 'student checklist' column is designed to be included in the developed checklist. The column requires students to tick the criteria that have been included in the report before submission. The initial design of the developed scoring checklist is shown in Figure 2.

Criteria	Student Checklist [✓]	Marks
Criteria 1		
Criteria 2		
⋮		⋮

Figure 2. First design of the developed checklist

Development

An in-depth literature review was performed to search for the important criteria of a lab report. Since the researcher decided to develop a detailed checklist, a list of lab report items has been recognized first. The items include title, abstract, keywords, introduction, materials and apparatus, methodology, tabulation of data, graph/chart, calculation, discussion, conclusion, reflection, and formatting. There are 47 criteria nested under 13 items in the first draft of the checklist. The first item is the title. Based on Table 5, the identified criteria for the title are correct title, name and ID, and experiment date. Leshe (2016), Beagles et al. (2016), and Hammerman (2008) stated that an appropriate title should be included in a lab report. Leshe and Beagles et al. also stated that name, student ID, and date should be included in the report. However, Leshe stated that the date is when the experiment is performed, while Beagles et al. stated that the date is when the report is written. The researcher considered both suggestions and thought that the experiment date would be better to be included in the report since students can recall when the experiment is done. All the mentioned criteria are considered important in a scientific lab report for the title item. Therefore, the researcher decided to include all the criteria in the checklist.

Table 5. Title criteria

Item	Criteria
Title	Correct title Name and ID Experiment date

The next item is the abstract. Based on Table 6, the criteria for the abstract are 'attempt a response', 'correct objective(s)', 'procedures and equipment used', and 'results and findings'. Attempt a response criterion is suggested by Killpack and Fulmer (2018) in their study. The item aims to give the students credit for trying to raise their motivation to complete the task. However, the study is not conducted in the lab report assessment context. Killpack and Fulmer conducted a study to develop a scoring tool for experimental design in biology courses. However, the researcher thought that this criterion was necessary to be included in this study. The main reason is this criterion can contribute to reducing the marks gap between all the three UOC experiments. Therefore, the 'attempt a response' criterion is included in most items of this study checklist. Beagles et al. (2016) and Hammerman (2008) stated that the abstract should include objective, procedure, and results. The abstract must describe the whole laboratory experiment without specific details so that the readers can decide whether they are interested to read the full text or not. Therefore, the researcher thought that these criteria are enough and necessary for the abstract item.

Table 6. Abstract criteria

Item	Criteria
Abstract	Attempt a response Correct objective(s) Procedures and equipment used Results and findings

The next item is the keywords. Based on Table 7, the criterion for the keywords is 'at least two relevant keywords stated'. Keywords are important words or concepts related to the experiment. Furthermore, keywords define the topic, field, research issue, etc., covered by any professional article. In research, an article with relevant keywords can help other researchers to find the article when searching for the topic. In addition, keywords enable ordinary users to access database data without having any prior understanding of structured query languages or database schemas (Yu et al., 2017). Therefore, the keyword is an important component in professional writing. The researcher thought that it would be beneficial for the students to get used to the professional writing style so that they are prepared to use it in the working environment. It is customary to list five to six keywords after the abstract section (Cuschieri et al., 2019). However, the researcher thought that 'at least two relevant keywords stated' criterion is enough to be included as part of their professional writing training.

Table 7. Keywords criteria

Item	Criteria
Keywords	At least two relevant keywords stated

The next item is the introduction. Based on Table 8, the criteria for the introduction are 'attempt a response', 'relevant theory or principle', 'relevant theory formula', and 'relate experiment with theory'. The introduction describes the problem and summarizes relevant research findings that provide context and key concepts (Hammerman, 2008). In an engineering lab report, Beagles et al. (2016) stated it is important to describe the experiment background in the introduction. The background should include any facts or theory involved in this experiment but not be exhaustedly explained (Turbek et al., 2016). The formula is also appropriate to be included but not necessarily derived from the first principles. Leshe (2016) also mentioned 'conceptuality' as a criterion in the introduction item. Therefore, the researcher decided to include the background as the criteria of the introduction since it can familiarize students with past research on the topic. The experiment background is split up into two criteria: (1) relevant theory or principle and (2) relevant theory formula. Finally, Hammerman also stated that the problem statement must be linked with relevant research that has been made. Therefore, the criterion 'relate experiment with theory' is necessary to be included in the introduction item.

Table 8. Introduction criteria

Item	Criteria
Introduction	Attempt a response Relevant theory or principle Relevant theory formula Relate experiment with theory

The next item is the materials and apparatus. Based on Table 9, the criteria for the materials and apparatus are 'attempt a response', 'use own experiment diagram/photo', and 'correct labeled diagram/photograph'. Materials and apparatus are important in lab experiments and reports. Leshe (2016) stated that materials and apparatus should be a bulleted list, while Beagles et al. (2016) stated that materials and apparatus should be presented in a labeled diagram. The researcher considered both suggestions and followed Beagles since engineering is related to physics. In chapter 4, a student from the needs analysis suggested making a short video as a method of lab assessment. The short video can be used as an evidence-based assessment for the lecturer to observe whether the students did the experiment correctly or not. Although the suggested duration was just 60 seconds, it still took time for the lecturer to assess all subgroup videos. Furthermore, making a short video also burdened the students since it involved video recording and editing activities. However, Wright et al. (2018) proposed a similar method by using a photograph. In their study, students are required to use their own pictures when submitting the laboratory portfolios. The findings indicate that the students can memorize all the steps taken during experimenting when referring to their own photos. Furthermore, a student also stated that he can still memorize the experiment even a week after the experiment was conducted. Therefore, by considering all the references, the researcher decided to use a labelled diagram as the presentation of the materials and apparatus, and the diagram must be their own experiment setup photo.

Table 9. Materials and apparatus criteria

Item	Criteria
Materials and Apparatus	Attempt a response Use own experiment diagram/photo Correct labeled diagram/photograph

The next item is the methodology. Based on Table 10, the criteria for the methodology are 'attempt a response', 'passive voice', 'correct instrumentation used', 'correct variables', and 'correct experiment description'. The methodology is a chronological description of the experimental steps performed and the equipment used. Turbek et al. (2016), Hammerman (2008), and Beagles et al. (2016) stated that methodology should include instrumentation and experiment description. Furthermore, Beagles et al. and Leshe (2016) also stated that methodology should include variables. The researcher considered all opinions and split the criteria as: (1) 'correct instrumentation used', (2) 'correct variables', and (3) 'correct experiment description'. Finally, the essential criterion for methodology is 'passive voice'. Beagles et al. stated that the methodology should be written in the passive voice to differentiate it from the experiment instructions. Turbek et al. also recommended the same style, but using a mixture of active and passive voice is also recommended to vary sentence structure and avoid repetitive clauses. Therefore, the researcher considered 'passive voice' essential to be included in the checklist.

Table 10. Methodology criteria

Item	Criteria
Methodology	Attempt a response Passive voice Correct instrumentation used Correct variables Correct experiment description

The next item is the tabulation of data. Based on Table 11, the criteria for the tabulation of data are 'attempt a response', 'labeled table', 'accurate data', 'correct significant figures', 'correct labeled units', and 'correct uncertainties'. Leshe (2016) and Turbek et al. (2016) stated that the table should be labeled so readers can easily refer to a particular table. Beagles et al. (2016) and Leshe also stated that the data should be organized in a table with correct significant figures and units. These criteria are considered by the researcher as appropriate criteria to be included in the checklist. Furthermore, Beagles et al. also stated that uncertainties should be included in the discussion as they can be a possible source of error in the experiment. The researcher thought that the measurement uncertainties should be included in the data table because the students would refer to the table when writing the discussion. Therefore, the 'correct uncertainties' criterion is included in the checklist. According to Talha et al. (2020), data accuracy is important in the experiment because inaccurate data may lead to faulty conclusions. Therefore, the researcher thinks the 'accurate data' criterion is necessary to be included in the checklist.

Table 11. Tabulation of data criteria

Item	Criteria
Tabulation of Data	Attempt a response Labelled table Accurate data Correct significant figures Correct labelled units Correct uncertainties

The next item is the graph or chart. Based on Table 12, the criteria for the graph or chart are ‘attempt a response’, ‘correct title’, ‘correct axes labels’, ‘correct labelled units’, and ‘correct graph line/curve’. Leshe (2016) and Turbek et al. (2016) stated that a graph should include a title. Beagles et al. (2016) and Leshe also stated that labelled axes and units are also important criteria in a graph. The researcher also considered these criteria essential, so they are included in the checklist. Beagles et al. stated that experimental data could often appear to lie along or close to a straight line. However, not all data appear as a straight line in the graph. Some data may appear as a curve. Therefore, the researcher decided to include ‘correct graph line/curve’ to indicate that the line/curve through the data points may be appropriate.

Table 12. Graph/chart criteria

Item	Criteria
Graph/Chart	Attempt a response Correct title Correct axes labels Correct labelled units Correct graph line/curve

The next item is the calculation. Based on Table 13, the criteria for the calculation are ‘correct calculation’ and ‘correct answer with unit’. This item is adapted from Leshe (2016). For the ‘correct calculation’ criterion, a footnote is included: if the data used the same calculation, state one sample only. The reason for showing one sample calculation is to avoid repetitive calculations that lead to longer lab report writings. The next criterion is ‘correct answer with unit’. Beagles et al. (2016) stated that the numbers presented in the text of a document should always be accompanied by an appropriate unit. Therefore, the researcher decided that this criterion is necessary for the calculation item.

Table 13. Calculation criteria

Item	Criteria
Calculation	Correct calculation *If the data used the same calculation, state one sample only* Correct answer with unit

The next item is the discussion. Based on Table 14, the criteria for the discussion are ‘attempt a response’, ‘accurate calculation/results deduction’, ‘relate dependent and independent variables’, ‘results achieved’, and ‘relate result with theory’. Discussion is the main component of a lab report (Leshe, 2016; Turbek et al., 2016). Hammerman (2008) stated that reasonable findings which are well supported by data would achieve a high mark in a rubric. Furthermore, an accurate deduction will explain the relationship between the experiment concept and the results obtained correctly. Therefore, the ‘accurate calculation/results deduction’ criterion is necessary to be included in the checklist. McLeod (2019) stated that it is crucial to identify exactly how the dependent and independent variables will be measured to ensure cause and effect are established. Furthermore, relating the dependent and independent variables could investigate the change in the independent variable, which could cause a possible impact on the dependent variable. Therefore, the researcher included the ‘relate dependent and independent’ criterion in the discussion item. Beagles et al. (2016) stated that the discussion must mention whether or not the results achieve the aims or prove/disprove the hypothesis. Furthermore, achieving results indicates that the experiment is well done. Therefore, the ‘results achieved’ criterion is important for the discussion item. Finally, the ‘relate result with theory’ criterion. Leshe stated that the discussion should be made to identify whether the results agree with the theory or not. Furthermore, Beagles et al. stated that when the findings are not coincide with the background theory, reasons should be proposed to clarify the problems. Therefore, the researcher thought that this criterion is appropriate to be included in the checklist.

Table 14. Discussion criteria

Item	Criteria
Discussion	Attempt a response Accurate calculation/results deduction Relate dependent and independent variables Results achieved Relate result with theory

The next item is the conclusion. Based on Table 15, the criteria for the conclusion are 'attempt a response', 'restate objective', 'quote data that met/did not meet the objective', and 'suggest at least ONE relevant suggestion for improvement'. Restating the objective in the conclusion item is necessary for a lab report (Beagles et al., 2016; Hammerman, 2008; Leshe, 2016). In addition, restating the objective may recall the actual aim of the experiment to the reader. Therefore, the researcher included the 'restate objective' criterion in the checklist. Leshe also stated that it is necessary to quote data that met or did not meet the objective in conclusion. As mentioned in the previous paragraph, Beagles et al. stated that the discussion must mention whether or not the results achieve the aims or prove/disprove the hypothesis. The researcher thought that it was appropriate to quote the findings data in the conclusion so readers could recall them from the discussion part. Furthermore, from past experience marking the lab reports during the document analysis, the researcher also noticed that students tend not to quote their faulty data because they think that the data were not appropriate to be concluded. As mentioned earlier, when the findings do not coincide with the background theory, reasons should be proposed to clarify the problems. Therefore, the researcher decided that the data must be quoted in the conclusion, whether it met or did not meet the objective. The final criterion is 'suggest at least ONE relevant suggestion for improvement'. Beagles et al. stated that suggestions for further work or potential improvements identified during the experiment could be suggested in conclusion. Furthermore, Leshe also stated that it is necessary to give suggestions to improve the experiment if the experiment is repeated. Therefore, the researcher decided to include the criterion in the checklist.

Table 15. Conclusion criteria

Item	Criteria
Conclusion	Attempt a response Restate objective Quote data that met/did not meet the objective Suggest at least ONE relevant suggestion for improvement

The next item is the reflection. Based on Table 16, the criterion for the reflection is 'at least three sentences for every person'. In chapter 4, one of the students from the needs analysis suggested reflection as a method of lab assessment. According to Zhang et al. (2020), students in their study were encouraged to write a reflection on their personal experience so that more individual and qualitative feedback and understanding of any aspect of the course could be collected and assessed to enhance the teaching and learning and make further improvement. Hammerman (2008) stated that students might make suggestions based on their findings or describe how the experiment results helped their understanding of a broader topic. Therefore, the researcher decided that this item was necessary for the lab assessment. The criterion is only 'at least three sentences for every person' because the researcher did not want to emphasize this criterion too much, since the mark provided only one. Furthermore, the researcher also wants the students to reflect anything involved during experiment whether the experimenting process, lab report writing or comments on the groupmates.

Table 16. Reflection criteria

Item	Criteria
Reflection	At least THREE sentences for every person

The final item is the formatting. Based on Table 17, the criteria for the formatting are 'justify all paragraphs', 'consistent font and size', 'italic symbols and regular font for units', and 'consistent spacing'. In scientific writing, it is crucial to identify the correct format necessitated by the journal (Cuschieri et al., 2019). Turbek et al. (2016) stated that following the writing format could facilitate the transfer of information from author to reader. Beagles et al. (2016) stated that the decision to include any formatting of a lab report to a certain extent is based on common sense. Therefore, in order to achieve the desired form of a professional lab report, the researcher decided that these criteria be included in the checklist.

Table 17. Formatting criteria

Item	Criteria
Formatting	Justify all paragraphs Consistent font and size Italic symbols and regular font for units Consistent spacing

The identification process resulted in 47 criteria nested under 13 items. However, these are not the finalized criteria for the lab report scoring checklist to be utilized in the UOC. The checklist will be revised critically in future studies. Figure 3 shows the first draft of the developed checklist. The identification process is considered important based on the current assessment tool, interview sessions, and literature support in the Indirect Assessment of Practical Skills, specific to UOC. However, the process of identifying suitable criteria can be replicated where applicable to another course to identify or generate criteria that fit the CLO of the course.

CRITERIA	STUDENT'S CHECKLIST (✓)	SCORE
Title		
Correct title		
Name and ID		
Experiment date		
Abstract		
Attempt a response		
Correct objective(s)		
Procedures and equipment used		
Results and findings		
Keywords		
At least two relevant keywords stated		
Introduction		
Attempt a response		
Relevant theory or principle		
Relevant theory formula		
Relate experiment with theory		
Materials and Apparatus		
Attempt a response		
Use own experiment diagram/photo		
Correct labelled diagram/photograph		
Methodology		
Attempt a response		
Passive voice		
Correct instrumentation used		
Correct variables		
Correct experiment description		
Tabulation of Data		
Attempt a response		
Labelled table		
Accurate data		
Correct significant figures		
Correct labelled units		
Correct uncertainties		
Graph/Chart		
Attempt a response		
Correct title		
Correct axes labels		
Correct labelled units		
Correct graph line/curve		
Calculation		
Correct calculation *If the data used the same calculation, state one sample only*		
Correct answer with unit		
Discussion		
Attempt a response		
Accurate calculation/results deduction		
Relate dependent and independent variables		
Results achieved		
Relate result with theory		
Conclusion		
Attempt a response		
Restate objective		
Quote data that met/did not meet the objective		
Suggest at least ONE relevant suggestion for improvement		
Reflection		
At least THREE sentences for every person		
Formatting		
Justify all paragraphs		
Consistent font and size		
Italic symbols and regular font for units		
Consistent spacing		
TOTAL MARKS		

Figure 3. First draft of the developed checklist

CONCLUSION

This study aims to identify the criteria for a scoring checklist to assess practical skills indirectly in an undergraduate optics course. The development processes have answered the research question of this study. In conclusion, a set of criteria to assess practical skills indirectly among undergraduates in an optics course has been identified. However, developing an assessment tool requires a deep analysis before any party can use it. Therefore, the tentative checklist is ready for further stages of analysis in future studies to complete all phases in the ADDIE model to develop a complete desired assessment tool.

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APPENDIX A

The summary of the identified criteria.

Code	Criteria	References	Justification
A	**Title**		
1	Correct title	(Beagles et al., 2016; Hammerman, 2008; Leshe, 2016)	The important aspect of a scientific report.
2	Name and ID	(Beagles et al., 2016; Leshe, 2016)	The important aspect of a scientific report.
3	Experiment date	(Beagles et al., 2016; Leshe, 2016)	The important aspect of a scientific report.
B	**Abstract**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Correct objective(s)	(Beagles et al., 2016; Hammerman, 2008; Leshe, 2016)	Describe the laboratory experiment without specific detail.
3	Procedures and equipment used	(Beagles et al., 2016; Hammerman, 2008)	Describe the laboratory experiment without specific detail.
4	Results and findings	(Beagles et al., 2016; Hammerman, 2008)	Describe the laboratory experiment without specific detail.
C	**Keywords**		
1	At least two relevant keywords stated	(Cuschieri et al., 2019)	Keywords define the topic, field, research issue, etc., covered by any professional article.
D	**Introduction**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempts may signify students' low motivation to complete the task.
2	Relevant theory or principle	(Beagles et al., 2016; Hammerman, 2008; Turbek et al., 2016)	Familiarize students with past research on the topic.
3	Relevant theory formula	(Beagles et al., 2016; Hammerman, 2008)	Familiarize students with past research on the topic.
4	Relate experiment with theory	(Hammerman, 2008)	Answer the research question and briefly describe the experiment
E	**Materials and Apparatus**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Use own experiment diagram/photo	(Wright et al., 2018)	Reflect on students' performance in laboratory skills and aid students' memories of the experiment for a long time.
3	Correct labeled diagram/photograph	(Beagles et al., 2016)	Students can apply their knowledge by identifying parts of a diagram/photo.
F	**Methodology**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Passive voice	(Beagles et al., 2016; Leshe, 2016; Turbek et al., 2016)	To differ between instructions and prose (writing language).
3	Correct instrumentation used	(Beagles et al., 2016; Hammerman, 2008; Turbek et al., 2016)	Describe materials, subjects, and equipment used. Incorrect instrumentation stated will confuse the reader.
4	Correct variables	(Beagles et al., 2016; Leshe, 2016)	All experimental investigations have variables
5	Correct experiment description	(Beagles et al., 2016; Hammerman, 2008; Turbek et al., 2016)	Explain the steps used throughout the experiment. The incorrect description will confuse the reader.
G	**Tabulation of Data**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Labeled table	(Leshe, 2016; Turbek et al., 2016)	Easy for the reader to refer
3	Accurate data	(Talha et al., 2020)	Data accuracy measures the degree to which data are correct. Inaccurate data leads to faulty predictions.
4	Correct significant figures	(Beagles et al., 2016; Leshe, 2016)	To show the data precision
5	Correct labeled units	(Beagles et al., 2016; Leshe, 2016)	The unit describes the quantity of the data.

6	Correct uncertainties	(Beagles et al., 2016)	One of the possible sources of error occurs in the experiment.
H	**Graph/Chart**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Correct title	(Leshe, 2016; Turbek et al., 2016)	Important identity of the graph/chart
3	Correct axes labels	(Beagles et al., 2016; Leshe, 2016)	Essential item for a graph/chart.
4	Correct labeled units	(Beagles et al., 2016; Leshe, 2016)	Essential item for a graph/chart.
5	Correct graph line/curve	(Beagles et al., 2016)	Indicate that the line/curve through the data points may be appropriate.
I	**Calculation**		
1	Correct calculation *If the data used the same calculation, state one sample only*	(Leshe, 2016)	Correct calculation shows the correct analysis for the experiment conclusion. One sample calculation is to avoid repetitive calculations that lead to longer lab report writings.
2	Correct answer with unit	(Beagles et al., 2016)	The correct answer indicates the accurate analysis method and data. The unit describes the quantity of the calculation answer.
J	**Discussion**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Accurate calculation/results deduction	(Hammerman, 2008)	An accurate deduction will explain the relationship between the experiment concept and the results obtained correctly.
3	Relate dependent and independent variables	(McLeod, 2019)	Investigate the change in the independent variable, which could cause a possible impact on the dependent variable.
4	Results achieved	(Beagles et al., 2016)	Achieving results indicates that the experiment is well done.
5	Relate result with theory	(Beagles et al., 2016; Hammerman, 2008; Leshe, 2016; Turbek et al., 2016)	To explain and pique readers' curiosity about the answer to the research question in the introduction.
K	**Conclusion**		
1	Attempt a response	(Killpack & Fulmer, 2018)	Credit for trying. Responses with no attempt may signify students' low motivation to complete the task.
2	Restate objective	(Beagles et al., 2016; Hammerman, 2008; Leshe, 2016)	It is proper to begin the conclusion with a sentence about the experiment. Restate the objective may recall the actual aim of the experiment to the reader.
3	Quote data that met/did not meet the objective	(Hammerman, 2008; Leshe, 2016)	Mention the results data from the discussion so readers can recall them.
4	Suggest at least ONE relevant suggestion for improvement	(Beagles et al., 2016; Leshe, 2016)	Make suggestions based on the findings for future improvement.
L	**Reflection**		
1	At least THREE sentences for every person	(Hammerman, 2008; Wright et al., 2018; M. J. Zhang et al., 2020)	To enhance teaching and learning and make future improvements.
M	**Formatting**	(Turbek et al., 2016)	Make information more accessible to the reader.
1	Justify all paragraphs		
2	Consistent font and size		
3	Italic symbols and regular font for units		
4	Consistent spacing		