# Development of a Rubric for Improved Understanding of IPLS Curricula

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In recent years, there has been a growing interest in shifting some of the basic presentation of the algebra-based physics curriculum in situations where it serves students with a background and/or major in the Life Sciences. Introductory Physics for Life Sciences (IPLS) courses are becoming more common however the courses are often created entirely separate from one another with very different goals and aims, making assessment of these courses very difficult, and necessarily individualistic. This paper presents the development of a rubric for categorizing specific aspects of an IPLS curriculum in such a way that would allow certain comparisons across curricula. Roughly speaking, it categorizes the <u>context</u> of specific questions as being physics or biology related, and then further categorizes the actual content and information necessary to answer the question as being related to physics or biology, thus allowing users to determine the proportion of questions are that are superficially biological. An application of the rubric to existing course material is presented.

## I. INTRODUCTION

Within the physics education research and biology education research communities, there has been recognition of the need to realign course content in physics with the curriculum competencies present in the fields of biology and other associated life sciences. To this end, individual researchers as well as the American Association of Physics Teachers (AAPT) have called for reform focusing on developing physics curriculum that fits with the expertise and background of life science majors [1]. The courses are often referred to as Introductory Physics for the Life Sciences, IPLS courses. To contend with ever-advancing technology - whether it be in medicine, research, or otherwise- life science students have an urgent need for a relevant and working foundation of physics [2]. It has long been accepted that the students enrolled in introductory algebra-based physics courses have different academic backgrounds and different intended careers than those students who are physics or engineering majors, with humorous distinctions appearing in literature as early as the 1960s [3]. Therefore, it stands to reason these students would benefit from a better-suited physics education, with content more pertinent and immediately applicable to their area of study. The necessary reform of physics courses geared towards these life science students has garnered early support, and a myriad of solutions in the form of modified curriculum have been brought forth. Many of these curricula are expected to be featured on the Living Physics Portal website due to launch in the Fall of 2018 [8]. However, not all of them successfully address the issues inherent in creating IPLS course materials [4]. As of the time of this paper, there's not yet an agreed upon set of outcomes for an IPLS course, and, likewise, there is no commonly agreed upon assessment for these proposed IPLS courses. However, at least one group has outlined what some of those goals may be, and implications for curricular design. [14] There primary conclusion is that Undergraduate education would benefit by further integration of science content across disciplines.

We offer additional input into this narrative by developing a rubric that attempts to capture the proportion of physics-relevant and biologically-relevant course content present in a given IPLS course. While most agree that an IPLS course must inherently be a physics course first, the goal is to include content that is authentically biological [6]. There are inherent epistemological differences in the "cultural components" [5] of physics and biology- especially regarding qualitative/quantitative manipulations versus conceptual reasoning. To ascertain what is meant by biologically relevant, we turn to the idea of authenticity, or 'ordinary practices of the culture' as expanded on by Watkins [6] from Brown et al. [7] There have been several physics textbooks and course offerings put forth that claim to be geared towards IPLS, but the content is often superficially biologically-based, wherein the student takes away no deeper understanding or appreciation of the biological system being discussed by engaging with the material [6]. In contrast, an authentically biologically-based course curriculum would grant knowledge and application of physics skills, while yielding a deeper insight into the biological systems in question [6].

We therefore propose a rubric that may aid in differentiating between the superficial and the authentic content of these courses. A superficial problem provides a biological relevant context but does not require any biological understanding or thinking to answer. An authentic

problem presents a relevant biological context and requires the use of biological (and perhaps also physics) concepts and ideas. The development and implementation of this rubric would be, at minimum, a resource for curriculum developers and educators to track the level of superficiality within a particular curriculum. To collaborate effectively as educators, we must ensure we are speaking the same language, and thus such a rubric would be a critical first step to the PER and AAPT community, allowing for clearer communication about the content of an IPLS course.

## II. METHODOLOGY

The ultimate goal of this research is to develop a rubric that can inform educators and curriculum developers as to the extent of the biological authenticity or superficiality in a particular IPLS unit or course. Toward this end, a first-order rubric was developed around a single curriculum with which the authors were most familiar, the Biomedical Physics Course at Portland State University [9, 10]. Given the differences that exist across IPLS curricula, it seemed wise to refine this rubric before consideration of additional IPLS curricula. This requires a brief description of the Biomedical Physics Course and the nature of the coding/categorization that was ultimately conducted.

### A. Biomedical Physics Course

The Biomedical Physics Course at Portland State University was developed and implemented by Ralf Widenhorn. Initially, the course was piloted as a summer elective course to be taken after the introductory three quarter, algebra-based physics sequence. The course featured medical doctors and specialists coming to class to talk about the use of physics in their specific medical practice or in the use of a particular medical device. The response from students was positive, and there were promising outcomes from the course that can be found in published literature [9, 10].

Since that time, Dr. Widenhorn has been adapting and developing select pieces of the pilot course for the introductory, algebra-based physics course. With this transition, Dr. Widenhorn continues to utilize the FlipIt Physics framework for disseminating course content, questions and homework to students in the course [11]. The lectures by medical professionals that were previously given live in class, were video-recorded and students watched them outside of class through the FlipIt Physics website. Additionally, students answered "Prelecture" questions on the videos they had just watched to confirm they had watched the video in its entirety. "Checkpoint questions" were aimed at getting students further engaged in the content and, at times, tested their understanding and ability to synthesize ideas. "Homework" questions were on the whole, much more difficult and were intended to synthesize students thinking about the content presented. (Note: the Biomedical Physics

Course uses only the FlipIt Physics content delivery system, not the algebra-based physics content provided by the company.) Ideally, these three main sections of questions (the Prelecture, Checkpoint, and Homework) would have a mixture of physics problems and biologically relevant questions. In the case of this course, the biological relevancy often touched on biomedical applications or scenarios.

### B. Developing the Rubric

#### 1. Previous Coding of IPLS Questions

Previous designations about the variation in problems encountered by students in an IPLS course have been used by Watkins, et al. to specifically look at "four categories to organize the various exam and homework questions that incorporated physics and/or mathematics" [6]. Watkins and colleagues looked at their own NEXUS curriculum [12] in designing these categories. As is expected some of their coding wasn't directly applicable to the Biomedical Physics Course at PSU and were therefore not considered. For instance, "synthesizing data" was not a common task asked from students in the Biomedical Physics Course and therefore was not included. As stated in the paper, these categories only examined questions that incorporated physics and mathematics. The goal for this work was to specifically look at the disciplinary context *and* content of all the student answered questions presented in the Biomedical Physics Course.

#### 2. Coding for Authentic Questions: Context, Content and Cognitive Task

One way we thought about the aims of this work was to operationalize to some extent what it meant for a question to authentically probe biological and physics content, versus presenting a biological context and proceeding to ask a question that only requires physics thinking. Through a process of Inductive Analysis, as outlined by Otero and Harlow [13], the authors determined patterns within the data set of questions whereby the *context* in which a question or problem was posed stood out as being noteworthy and yet distinct from the scientific *content* into which the question was probing. Further still, the actual cognitive task that students were asked to do in order to solve the problem didn't have any discernable connection to either the context or the content of the question, so we created a third general group of codings to capture that additional information.

Within the Context Category, the questions most commonly fell into one of three distinct groups, a Physics context group, an Anatomy and Physiology (A&P) group and a Biomedical group. It may be that a later rubric would simply bin these last two groups together, however given the Biomedical nature of the curriculum under study, the two categories were kept distinct. A Biomedical context, typically referred to a scenario with the use of a biomedical device, or a biomedical treatment of some type, while an

A&P context dealt with the inner-workings of a living being, most often a person, without the medical connection. Questions are assigned to the Physics based context when there was not a clear biological context available. For clarity, the context is how we think a student would interpret a question, and how they might frame what the question is going to be probing.

Within the Content Category, careful attention was given to the domain of science the question was actually probing. Was the question ultimately a physics question, a biology question, or a mixture of the two? Questions were coded as consistent if the context presented was within the same science domain as the content, whereby if there was some inconsistency, the question was coded as being superficial. Without exception, the superficial questions coded were all presented in a biological context of some type but were ultimately probing physics content, not the other way around.

Within the Cognitive Task Category, questions were identified as using 1. basic recall, 2. plug-and-chug, or falling within a broad category of 3. conceptual reasoning.

## III. DATA AND RESULTS

The data are presented with results from the Context Categories, the Content Categories, and the Cognitive Task Categories. Two individual researchers with supervision form a third researcher coded all the items for several units within the Biomedical Physics Course. Presented are one section of that data. Interrater reliabilities for codings were greater than 85%, and any differences in coding were discussed among coders and resolved. The unit presented here in Figures 1-3 is from a newly developed unit of the Biomedical Physics Course called Physical Therapy Module. This unit seemed to contain a lot of relevant questions, and thus it is provided as an example. The goal of presenting this data is not to showcase an exemplar or poor instructional unit for this course, rather it is to demonstrate that such a designation is possible and to provide a sample of what data from this analysis can look like.

### A. Context Category Results

The data in Figure 1 show that 36% of the questions from this unit were coded as A&P, while 17% were identified as being Biomedical based.

Overall, the context of the questions in this single unit from the Biomedical Physics Course were evenly split between physics and biology-relevant questions.

### B. Content Category Results

The vast majority of questions from this unit were consistent across content and context. Figure 2 shows that only 14% of questions were superficial, meaning that they presented a biological context, but were solely probing physics knowledge. This seems like a low proportion of

superficial questions, however more data is needed to ascertain the variation of superficiality in various curriculum. It's worth nothing that only 1% of all questions in this unit were deemed to probe both physics knowledge and biology-relevant knowledge; a low proportion.



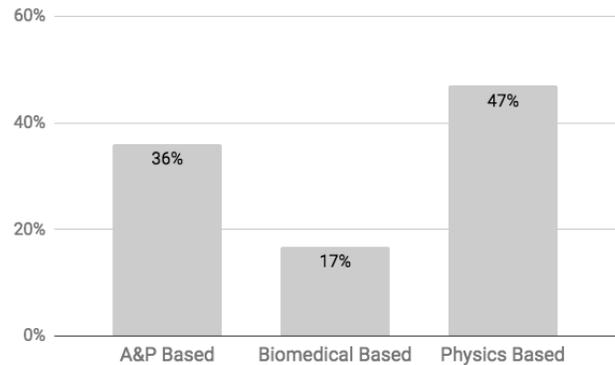FIG 1. The context category proportions for Prelecture, Checkpoint and Homework questions ($N = 83$) in the Physical Therapy Module from the Biomedical Physics Course. The data were parsed by Anatomy and Physiology (A&P), Biomedical and Physics Based topics.
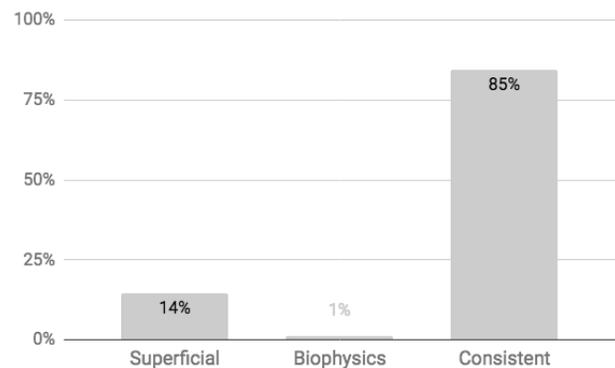


FIG 2. The content consistency of a particular Prelecture, Checkpoint, or Homework Question compared to the context in which it was presented. (Not shown, the remaining questions were consistent across context and content.)

### C. Cognitive Task Results

Although still in development, the rubric aims to categorize the cognitive task incumbent on the student for the various problems they encounter in a particular unit. While the context and content can tell a great deal about the authenticity and superficiality of a question, if a small proportion of questions engage students on a deep level, it's unlikely substantive learning will occur. As one can see in Fig 3., a large proportion of the questions from this unit required only recall and plug-and-chug manipulations to answer. That is, recall questions are questions that asked for

a simple regurgitation of some statement, term, phrase or idea, whereas plug-and-chug questions are numerical questions where the application of a rote formula can be used to achieve an answer. Conceptual Reasoning questions where those questions that went beyond these two previous categories, that often required a description of a resulting circumstance within the question. While this isn't the main thrust of this work's investigation, it is an area of potential fruitful exploration.
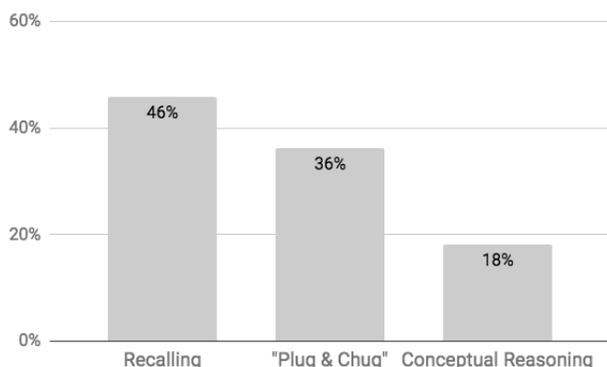


FIG 3. The cognitive task proportions show that most Prelecture, Checkpoint and Homework Questions ($N = 83$) from the Physical Therapy Module in the Biomedical Physics Course are Recall and "Plug and Chug"-type questions.

## IV. CONCLUSIONS AND FUTURE WORK

The IPLS Authenticity and Superficiality rubric is a tool in development. As the rubric is applied to curricular materials from additional IPLS courses, developments and revisions to appropriately categorize and describe unique curricular aspects are expected. However, the essential task will remain the same: determining the proportion of questions and tasks whose <u>contexts</u> *and* <u>content</u> are focused on biology and/or physics.

An essential takeaway from this work is that there is no well-defined goal in mind for the optimal proportion of biologically authentic questions. IPLS is, for most faculty, still a physics course, so it's reasonable that many questions are purely physics in both context and content. However, this rubric should aid faculty in providing a more objective lens on the extent to which their curriculum is authentic, in that it can cast light on the proportion of those commonly seen end-of-chapter problems that are superficially biological. An alleged IPLS curriculum that has a high proportion of superficially biological questions may warrant further scrutiny by the curriculum developer.

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