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A Discussion on the Application of Micro-lectures in University Physics Laboratory Teaching

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Abstract: The university physics laboratory course is the foundational component through which science and engineering students receive systematic experimental training. However, inadequate pre-lab preparation, in-class exposition that encroaches on hands-on time, and unguided post-laboratory data processing are intertwined, and none of them can be resolved merely by increasing contact hours. This paper traces the conceptual evolution of the micro-lecture and its resource composition to delineate its functional boundaries: micro-lectures are well suited to presenting instrument structure, localized manipulations, and data-processing methods, but they cannot substitute for instrument adjustment or situated judgement. Accordingly, we propose calibrating the scale of resource development against a checklist of recurring difficulties, and constructing three categories of resources by purpose: principles and instruments, operational essentials and common faults, and data processing and reporting. Instruction is shifted to the pre-lab stage, repeated lecturing is replaced by question-based checks, first-pass data processing is returned to the laboratory session, and assessment is reweighted toward pre-lab preparation and in-process performance. Existing comparative trials indicate that video-based preparation improves conceptual mastery and report quality; nevertheless, the constraints imposed by production effort, version maintenance, and faculty workload warrant validation against controlled data from two consecutive student cohorts before any large-scale adoption.

Keywords: Micro-lectures; Process-oriented Assessment; Data Processing.

1. Introduction

The university physics laboratory course is a compulsory foundational course in science and engineering programmes. It marks the beginning of students' systematic study of experimental methods and techniques, and underpins subsequent course design and discipline-specific laboratory work. Covering mechanics, thermodynamics, electricity, optics, and modern physics, the course serves both as a venue for verifying physical concepts and as a training ground for measurement methodology, error analysis, and data processing. Because the course is offered at scale across multiple majors, each experiment must be repeated for numerous cohorts **within one semester. The resulting load of lecturing and report grading** compresses the time available for individual guidance [1][2].

The literature attributes the course's constraints to three factors: inadequate pre-lab preparation, difficulty in allocating in-class time, and poor conditions for post-lab consolidation [1][2]. When the pacing of theory and laboratory courses is misaligned, students tend to follow prescribed procedures mechanically and rarely raise questions on their own initiative [3]. Shen and colleagues measured the time budget of a laboratory session and found that a complete introduction to one experiment typically requires more than 30 minutes; once students have additionally clarified the procedure and adjusted the apparatus, the time left for actual measurement is already severely limited [1]. Together with reduced contact hours and an oversized catalogue of experiments, these constraints make discipline-specific adaptation of laboratory content difficult [2][4].

Micro-lectures entered Chinese teaching practice after 2010. Their conceptualization has evolved from an emphasis on micro-resource composition, through that of a brief but complete teaching activity, to that of an online micro-course supporting diverse learning modes [5]. Most existing studies concentrate on conceptual clarification, resource production, and the pre-lab phase, while comparatively little attention has been paid to the articulation of pre-, in-, and post-class stages or to the accompanying assessment system. The present paper addresses these two gaps, specifies the conditions under which the proposed scheme is applicable, and proposes a procedure for evaluating its effects.

2. Current Teaching Practice and the Functional Boundaries of Micro-lectures

2.1. Interdependence of the Three Stages

At present, pre-lab work largely consists of completing a pre-lab report. Laboratory manuals usually provide only the governing formulae and a schematic diagram, so that students can hardly form a mental model of complex manipulations from text alone [1]. For some experiments, the corresponding theory has not yet been covered in the lecture course, which creates a prerequisite obstacle to understanding the underlying principles [1][2]. Students generally assume that the apparatus will accomplish the experiment by itself, and the preparatory stage is consequently devalued. To ensure procedural correctness and instrument safety, instructors are obliged to explain principles, instrument structure, and precautions from scratch during class. A uniform lecture cannot accommodate differences in students' prior laboratory training: excessive exposition encroaches on hands-on time, whereas insufficient exposition reduces students to mechanically following a recipe. Neither extreme satisfies the course objectives [2].

The pressure on in-class time propagates into the post-lab stage. Once students leave the laboratory, review lacks the support of physical apparatus and relies only on a concise manual and the raw data sheet [2]. Although uncertainty

evaluation, significant-figure arithmetic, the method of successive differences, and least-squares fitting are introduced collectively in the introductory lecture, their implementation differs from one experiment to another. When students process data on their own and encounter difficulties, guidance is unavailable, and mutual reference to peers' data or the perpetuation of errors readily occurs [1]. An assessment scheme centred almost exclusively on the laboratory report can neither reflect procedural correctness nor detect data fabrication [6]. Pre-lab work, in-class lecturing, and report writing thus form a causal chain: weak preparation forces repeated in-class exposition; insufficient class time displaces data processing; and the absence of post-lab guidance consolidates errors in manipulation and analysis, which in turn compromises subsequent experiments.

These problems do not arise from inadequate student effort. Limited laboratory space, the number of instrument sets, and fixed contact hours, together with imperfect alignment between the experiment catalogue and the theory syllabus, constitute the structural conditions of a large-enrolment foundational laboratory course [2][4]. A reform that merely adds learning materials without changing the teaching flow and the assessment system will therefore yield little effect.

2.2. Conceptual Evolution and Applicability Boundaries

Reviewing more than ten representative Chinese definitions of the micro-lecture proposed between 2011 and 2013, Hu and colleagues argue that scholarly understanding progressed from a resource conception centred on the teaching video and its associated materials, through a conception of the micro-lecture as a short yet complete teaching activity, to an online video course supporting multiple learning modes [5]. The brevity and density of micro-lectures imply highly concentrated knowledge points and a corresponding fragmentation of knowledge construction. Content is therefore broken down into short segments and reorganized, in a scenario-based manner, into a unit that allows learners to direct their attention quickly to the key and difficult points [5]. Song and colleagues identify instructional design, media assets, exercises and tests, teaching reflection, and feedback comments as constituent elements, treating the micro-lecture as a thematically focused resource package [7]. Chen and colleagues likewise list micro-lesson plans, micro-exercises, micro-courseware, micro-reflection, and micro-commentary, and characterize the micro-lecture as semi-structured [6]. Most studies keep individual clips within roughly ten-odd minutes, a compact format suited to repeated viewing on mobile terminals [7].

The intrinsic affinity between micro-lectures and laboratory teaching lies in the fact that instrument structure, localized operations, and data-processing procedures can all be visualized, and in the tendency of learning difficulties to cluster at particular local steps. The boundaries of application, however, require explicit specification. First, a complete video of the entire experiment should not be provided; room must be left for actual manipulation, trial-and-error exploration, and discrimination of phenomena. Video content should concentrate on local issues such as the formation mechanism of interference fringes or the adjustment of a reading mechanism. Second, tactile skill and situated judgement cannot be acquired by watching. The control of the backlash of the fine-adjustment knob on a Michelson interferometer, and the unidirectional approach to a reading microscope that avoids screw-pitch error, can be formed only through work with the physical instrument [8]. Third, instruments shown in publicly available online videos generally differ from those actually used in the course in model, panel layout, and operating principle. Manufacturers' variations or equipment renewal can render an existing video substantially inconsistent with the current setup [4]; preparing from such a video may instead increase cognitive load. Ni therefore recommends producing in-house clips matched to the apparatus available in one's own laboratory [4]. Fourth, the practical value of personally completing circuit connections, optical alignment, and raw-data reading cannot be replaced: micro-lectures and MOOCs serve only as a useful complement to conventional laboratory instruction.

Recording micro-lectures entails specific design requirements. Because live interaction with students is absent, teachers must pre-design questions, prompts, and evaluative remarks so that the recording, though silent, keeps anticipating what the learner will ask [7]. Content pacing must balance information density against exposition rate: key steps require a slower tempo and rigorously accurate wording, while non-essential material may be treated briefly [7]. Liu and colleagues note that when teachers cannot observe students' responses in real time, judging the relative weight of key and difficult points and controlling the pace become more demanding [9].

3. Proposed Reform

3.1. Constraining Resource Scale by a Checklist of Difficulties

Producing micro-lectures is a systematic undertaking. Shu and colleagues divide the workflow into five phases—front-end analysis, script design, material preparation, software editing, and testing/evaluation—and observe that preparation demands substantially more effort than recording itself, with the script largely determining the final quality [3]. Videos should therefore not be produced for every experiment. Instead, a checklist of recurring difficulties should be distilled from common errors in successive years' laboratory reports, and one or two core difficulties selected for micro-lecture development per experiment. Experiments should also be screened: conventional verification-type experiments are generally not amenable to direct conversion into inquiry-based ones, whereas experiments admitting multiple principles or multiple methodological routes are better carriers for reform. Determination of Young's modulus, measurement of moment of inertia, and oscilloscope operation belong to this latter category.

Resources should be organized by purpose rather than by textbook chapter, and grouped into three categories: principles and instruments; operational essentials and common faults; and data processing and reporting. Shao and colleagues classify micro-lectures into introductory, methodological, instrumental, and extension videos to serve different learning needs [10]. A purpose-based classification helps fix, at the scripting stage, the moment of use and the accompanying task for each clip. Principle-oriented videos should be differentiated according to the knowledge gaps of different majors: in the pull-off method for measuring the surface tension coefficient, for instance, the mechanical principle and the transducer principle pose different difficulties and should not receive equal instructional weight. Modeling-oriented experiments admit a different

organization. Taking the amplitude–frequency characteristics of a series RLC circuit as an example, Shu and colleagues proceed through model assumptions, parameter selection, model construction, experimental verification, and model extension. Students are first guided to construct an ideal-component model before wiring the circuit, and are then led to revise that model through the fault case in which "the grounded terminal of the AC voltmeter causes the reading not to equal the potential difference across the resistor" [3]. Operation-oriented videos may cover error-prone steps such as the half-adjustment procedure of the spectrometer or the configuration of a photogate digital millisecond timer for different measurands. Data-processing videos address least-squares computation in Excel, the method of successive differences, uncertainty combination, and significant-figure arithmetic, with individual clips generally limited to five to eight minutes [4].

The content and point of use of the three categories may be specified as follows. Principles-and-instruments resources belong to the pre-lab stage and cover the amplification principle of the optical lever, the range and zero reading of the micrometer, the transducer principle in the pull-off method, and the ideal-component model of the series RLC circuit; three to five guiding questions are attached and checked orally in class. Operational-essentials and common-fault resources serve both pre-lab preparation and in-class consultation, and cover backlash control of the Michelson fine-adjustment knob, unidirectional approach in the Newton's-rings reading mechanism, spectrometer half-adjustment, and wiring deviations caused by the AC voltmeter's grounded terminal; each group submits a short clip of a key phenomenon. Data-processing and reporting resources cover Excel-based least squares, successive differences, uncertainty combination, and significant figures; the first-pass calculation is completed in class, measurements with conspicuously large errors are repeated, and the clips are revisited on demand during report writing.

Production standards should be uniform: stable, sharp imagery with sensible framing; clear audio; subtitles for the main instructional segments [6][7]; a rapid entry into the topic; a single expository thread; precise and logically concise language; succinct board summaries; and a one-to-two-minute closing synthesis of the disciplinary method [6][7]. Courseware should be accompanied by exercises, tests, key and difficult points, and commonly confused concepts [7]. Completed scripts are reviewed by a second teacher, and videos are named uniformly with version records maintained. The three categories above constitute a resource-development inventory, not a learning sequence: students consult only the categories relevant to the experiment at hand.

3.2. Articulating the Pre-, In-, and Post-lab Stages

One week before the session, clips are released on the course platform together with three to five guiding questions, so that preparation is question-driven rather than measured by viewing duration; students arrive at the laboratory with unresolved questions. Approximately ten minutes at the start of class are devoted to oral checks, with preparation marks recorded on the spot; those who do not meet the threshold review the material afterwards, without consuming hands-on time [1]. Shen and colleagues likewise treat online viewing of laboratory micro-lectures as part of pre-lab work and use questioning to probe understanding of principles [1]. Without this enforcement, the video merely becomes a formal substitute for the pre-lab report.

In class, the instructor briefly addresses the common problems revealed by the check and devotes the remaining time to supervising manipulation and individual coaching. Discussion questions may be built around genuine experimental difficulties: in the Newton's-rings experiment, the origin of screw-pitch error, the rationale for measuring ring diameters rather than radii, and the influence of microscope magnification on the result. After observing the drive mechanism, students propose unidirectional or bidirectional measurement schemes. An online quiz with automatic scoring may be administered at the end of the session. Interactive segments must not degenerate into the instructor answering his or her own questions, nor may a single script be reused across all cohorts. As process evidence, each group submits a short clip of a key phenomenon—for example, Lissajous figures on the oscilloscope, or a comparison of interference fringes under varying parameters. Because reference frequencies and parameter settings differ across groups, both the observed patterns and the associated values differ, which discourages replication of phenomena and data. Meng and colleagues require the whole group to report jointly, so that the manipulation is not performed by a single member while the entire group shares one set of results [8].

The crucial post-lab adjustment is to return first-pass data processing to the laboratory session, where students can seek immediate help when blocked [1]. Data with conspicuously large errors are remeasured. Topical clips remain available for on-demand review during report writing [4]. Students with spare capacity may apply to undertake extension or design experiments in the open laboratory, or use numerical simulation to supplement field maps and data relations that the laboratory cannot display [8]. Resources should be distributed through the course platform alone; multiple channels—platform, class group chats, e-mail—create version confusion [4].

3.3. Corresponding Adjustment of Assessment

Grading on the laboratory report alone cannot reflect the conduct of the experiment [6]; Shen and Zhang argue for increasing the weight of preparation and reducing that of data processing [1]. Accordingly, preparation accounts for one quarter of the total mark, in-process performance for one fifth, and the report for the remaining eleven twentieths. The exact weights should be fixed after a one-semester small-scale pilot rather than imposed across all experiments at once.

Process-oriented assessment requires operable carriers. Meng and colleagues decompose evaluation into three sequential stages—pre-lab selection of principles and instruments, in-class manipulation and phenomenon presentation, and post-lab reporting on data and data analysis by video—with each stage accessible only after the preceding one has been passed [8]. The instrument-selection item tests whether range and precision match the measurand: although the micrometer is a length-measuring tool, it cannot directly measure the minute elongation of a thin wire in the elongation method for Young's modulus, and students must select an indirect technique such as the optical lever [8]. The data-analysis report must explain the regularities, error sources, and uncertainty with reference to graphs and tables, with the instructor posing experiment-specific questions [8]. Shao and colleagues recommend rapid retrieval of evaluation results

via mobile devices and networks, and revision of video content and instructional segments in light of those results [10].

Questioning, video checks, and platform trace logs all add to faculty workload. Rubrics must therefore be concise, checks conducted at random, and presentations time-limited if the measures are to remain sustainable in the long run. The teacher's role shifts from lecturer to facilitator and respondent: in class the instructor must vet the feasibility of proposed schemes, diagnose the source of difficulties, and patrol continuously—a demand on diagnostic judgement considerably higher than that of repeated lecturing [6][10].

4. Implementation Constraints and Effect Validation

Existing empirical studies provide useful reference points. Liu and colleagues established a within-class comparison for the Newton's-rings determination of the curvature radius of a plano-convex lens. One group read the manual and wrote a pre-lab report before receiving a lecture and proceeding to the measurement, while the other prepared by viewing a micro-lecture video and began manipulation directly upon entering the laboratory, with the instructor available for guidance [9]. Of 51 pre-session questionnaires distributed, 50 valid returns were obtained, and 23 from each group were analysed. The video-preparation group showed better mastery of the relevant knowledge and more comprehensive reasoning. More than 80% of the students who viewed the video identified flexible timing as its principal advantage, and 90% considered it highly helpful for end-of-term revision [9]. In her own course, Ni found that students who were required to watch self-recorded clips assembled and adjusted the instruments more quickly and obtained better measurements. After a micro-lecture on Excel-based data processing was recorded, errors in the calculation of Young's modulus and its uncertainty in reports on that experiment decreased, and the distribution of report scores improved accordingly [4]. These findings, however, pertain to individual courses or individual experiments, with small samples and limited experiment coverage; they cannot be generalized directly.

Four constraints bear on the sustained operation of the scheme. First, production is time-intensive, available resources remain scarce, and research on application models and effect measurement for information technology in laboratory teaching is still insufficient [9]; resources should therefore be built incrementally against the difficulty checklist, with explicit responsibility for version maintenance. Second, videos must be re-recorded whenever instruments are renewed, since a clip inconsistent with the physical apparatus is more misleading than no clip at all [4]. Third, the misalignment between theory and laboratory syllabi that unsettles students' readiness can be mitigated by micro-lectures supplying principle explanations, but cannot be resolved at the level of curriculum scheduling by them [3]. Fourth, effectiveness must be tested against the course's own comparative data. An A/B group design may be adopted, using a common concept questionnaire and a common report rubric, and logging the distribution of video revisits during the end-of-term revision period [9]. Data from two consecutive years should not constitute the sole basis of evaluation; resource counts, platform access statistics, and related indicators should be incorporated into the evaluation framework.

5. Conclusion

The essence of introducing micro-lectures into university physics laboratory teaching is to release finite class time from repeated exposition and return it to instrument adjustment, phenomenon observation, and data judgement. Resource development should be governed by a checklist of difficulties; the three stages should be articulated through questioning and on-the-spot processing; and assessment should emphasize preparation and in-process performance. These three adjustments must proceed in concert—altering any one in isolation yields poor results. Modeling before experimentation and guiding manipulation by questions are intended to deepen understanding of principles, not to have videos perform the operations on students' behalf. The effectiveness of the reform is best judged against controlled data from two consecutive student cohorts.

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