

## Standards and Expectations for the Instrumentation program

This document lists some of the general expectations and standards maintained in all second-year (200-level) Instrumentation courses. These standards and expectations are formally discussed with students during the INST200 course (“Introduction to Instrumentation”) and contained in every 200-level course worksheet for convenient reference.

These standards, as well as the teaching philosophy represented therein, are the product of many years of concentrated testing and development. The over-arching goal is to develop independent and responsible agency within each and every student. This is done by challenging students with significant responsibilities in self-directed learning and practical task completion, providing opportunities to either succeed or fail according to each student’s effort.

In an effort to continuously improve, the entire curriculum is reviewed and revised as necessary achieve its stated goal. Student performance in school and graduate performance in the workplace are the benchmarks by which success is measured. If a tested proposal results in improved academic and/or workplace performance, it is adopted; if a tested proposal fails to improve academic or workplace performance, it is rejected.

This document is divided into several sections:

- **General Values and Expectations:** outlines the major values upheld in these courses and the expectations of each student.
- **Program Outcomes:** outlines the outcomes expected of every student by graduation.
- **Inverted Session Formats:** describes the daily routine of classroom (theory) sessions, central to the development of self-directed learning.
- **Question 0:** a collection of tips for effective learning and problem-solving.
- **How To . . .** a set of answers to frequently asked questions, mostly describing how to locate specific resources.

## General Values, Expectations, and Standards

Success in this career requires professional integrity, resourcefulness, persistence, close attention to detail, and intellectual curiosity. If you are ever in doubt as to the values you should embody, just ask yourself what kind of a person you would prefer to hire for your own enterprise. Those same values will be upheld within this program.

**Learning** is the purpose of any educational program, and a worthy priority in life. Every circumstance, every incident, every day here will be treated as a learning opportunity, every mistake as a “teachable moment”. Every form of positive growth, not just academic ability, will be regarded as real learning.

**Responsibility** means *ensuring* the desired outcome, not just *trying* to achieve the outcome. To be a responsible person means you *own* the outcome of your decisions and actions.

**Integrity** means being honest and forthright in all your words and actions, doing your very best every time and never taking credit for the achievement of another.

**Safety** means doing every job correctly and ensuring others are not endangered. Lab safety standards include wearing closed-toed shoes and safety glasses in the lab room during lab hours, wearing ear protection around loud sounds, using ladders to reach high places, using proper lock-out/tag-out procedures, no energized electrical work above 30 volts without an instructor present in the lab room, and no power tool use without an instructor present in the lab room.

**Diligence** in study means exercising self-discipline and persistence, realizing that hard work is a necessary condition for success. This means, among other things, investing the necessary time and effort in studying, reading instructions, paying attention to details, utilizing the skills and tools you already possess, and avoiding shortcuts. Diligence in work means the job is not done until it is done *correctly*: all objectives achieved, all problems solved, all documentation complete, and no errors remaining.

**Self-management** means allocating your resources (time, equipment, labor) wisely, and not just focusing on the closest deadline.

**Communication** means clearly conveying your thoughts and paying attention to what others convey, across all forms of communication (e.g. oral, written, nonverbal).

**Teamwork** means working constructively with your classmates to complete the job at hand. Remember that here the first job is *learning*, and so teamwork means working to maximize everyone’s learning (not just your own). The goal of learning is more important than the completion of any project or assignment.

**Initiative** means recognizing needs and taking action to meet those needs without encouragement or direction from others.

**Representation** means your actions reflect this program and not just yourself. Doors of opportunity for all BTC graduates may be opened or closed by your own conduct. Unprofessional behavior during tours, jobshadows, internships, and/or jobs reflects poorly on the program and will negatively bias employers.

**Trustworthiness** is the result of consistently exercising these values: people will recognize you as someone they can rely on to get the job done, and therefore someone they would want to employ.

**Respect** means acknowledging the intrinsic value, capabilities, and responsibilities of those around you. Respect is gained by consistent demonstration of valued behaviors, and it is lost through betrayal of trust.

## General Values, Expectations, and Standards (continued)

**Punctuality and Attendance:** late arrivals are penalized at a rate of 1% grade deduction per incident. Absence is penalized at a rate of 1% per hour (rounded to the nearest hour) except when employment-related, school-related, weather-related, or required by law (e.g. court summons). Absences may be made up by directing the instructor to apply “sick hours” (12 hours of sick time available per quarter). Classmates may donate their unused sick hours. Sick hours may not be applied to unannounced absences, so be sure to alert your instructor and teammates as soon as you know you will be absent or late. Absence on an exam day will result in a zero score for that exam, unless due to a documented emergency.

**Mastery:** any assignment or objective labeled as “mastery” must be completed with 100% competence (with multiple opportunities to re-try). Failure to complete by the deadline date caps your grade at a C-. Failure to complete by the end of the *next* school day results in a failing (F) grade for that course.

**Time Management:** Use all available time wisely and productively. Work on other useful tasks (e.g. homework, feedback questions, job searching) while waiting for other activities or assessments to begin. Trips to the cafeteria for food or coffee, smoke breaks, etc. must not interfere with team participation.

**Orderliness:** Keep your work area clean and orderly, discarding trash, returning tools at the end of every lab session, and participating in all scheduled lab clean-up sessions. Project wiring, especially in shared areas such as junction boxes, must not be left in disarray at the end of a lab shift. Label any failed equipment with a detailed description of its symptoms.

**Independent Study:** the “inverted” instructional model used in this program requires independent reading and problem-solving, where every student must demonstrate their learning at the start of the class session. Question 0 of every worksheet lists practical study tips. The “Inverted Session Formats” pages found in every worksheet outline the format and grading standards for inverted class sessions.

**Independent Problem-Solving:** make an honest effort to solve every problem before seeking help. When working in the lab, help will not be given unless and until you run your own diagnostic tests.

**Teamwork:** inform your teammates if you need to leave the work area for any reason. Any student regularly compromising team performance through absence, tardiness, disrespect, or other disruptive behavior(s) will be removed from the team and required to complete all labwork individually. The same is true for students found inappropriately relying on teammates.

**Communication:** check your email daily for important messages. Ask the instructor to clarify any assignment or exam question you find confusing, and express your work clearly.

**Academic Progress:** your instructor will record your academic achievement, as well as comments on any negative behavior, and will share all these records with employers if you sign the FERPA release form. You may see these records at any time, and you should track your own academic progress using the grade spreadsheet template. Extra-credit projects will be tailored to your learning needs.

**Office Hours:** your instructor’s office hours are by appointment, except in cases of emergency. Email is the preferred method for setting up an appointment with your instructor to discuss something in private.

**Grounds for Failure:** a failing (F) grade will be earned in any course if any mastery objectives are past deadline by more than one school day, or for any of the following behaviors: false testimony (lying), cheating on any assignment or assessment, plagiarism (presenting another’s work as your own), willful violation of a safety policy, theft, harassment, sabotage, destruction of property, or intoxication. These behaviors are grounds for immediate termination in this career, and as such will not be tolerated here.

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## Program Outcomes for Instrumentation and Control Technology (BTC)

### #1 Communication

Communicate and express concepts and ideas across a variety of media (verbal, written, graphical) using industry-standard terms.

### #2 Time management

Arrives on time and prepared to work; Budgets time and meets deadlines when performing tasks and projects.

### #3 Safety

Complies with national, state, local, and college safety regulations when designing and performing work on systems.

### #4 Analysis and Diagnosis

Analyze, evaluate, and diagnose systems related to instrumentation and control including electrical and electronic circuits, fluid power and signaling systems, computer networks, and mechanisms; Select and apply correct mathematical techniques to these analytical and diagnostic problems; Select and correctly use appropriate test equipment to collect data.

### #5 Design and Commissioning

Select, design, construct, configure, and install components necessary for the proper function of systems related to instrumentation and control, applying industry standards and verifying correct system operation when complete.

### #6 System optimization

Improve technical system functions by collecting data and evaluating performance; Implement strategies to optimize the function of these systems.

### #7 Calibration

Assess instrument accuracy and correct inaccuracies using appropriate calibration procedures and test equipment; Select and apply correct mathematical techniques to these calibration tasks.

### #8 Documentation

Interpret and create technical documents (e.g. electronic schematics, loop diagrams, functional diagrams, P&IDs, graphs, narratives) according to industry standards.

### #9 Independent learning

Select and research information sources to learn new principles, technologies, and techniques.

### #10 Job searching

Develop a professional resume and research job openings in the field of industrial instrumentation.

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## Methods of instruction

This course develops self-instructional and diagnostic skills by placing students in situations where they are required to research and think independently. In all portions of the curriculum, the goal is to avoid a passive learning environment, favoring instead *active engagement* of the learner through reading, reflection, problem-solving, and experimental activities. The curriculum may be roughly divided into two portions: *theory* and *practical*. All “theory” sessions follow the *inverted* format and contain virtually no lecture.

### Inverted theory sessions

The basic concept of an “inverted” learning environment is that the traditional allocations of student time are reversed: instead of students attending an instructor-led session to receive new information and then practicing the application of that information outside of the classroom in the form of homework, students in an inverted class encounter new information outside of the classroom via homework and apply that information in the classroom session under the instructor’s tutelage.

A natural question for instructors, then, is what their precise role is in an inverted classroom and how to organize that time well. Here I will list alternate formats suitable for an inverted classroom session, each of them tested and proven to work.

#### Small sessions

Students meet with instructors in small groups for short time periods. Groups of 4 students meeting for 30 minutes works very well, but groups as large as 8 students apiece may be used if time is limited. Each of these sessions begins with a 5 to 10 minute graded inspection of homework with individual questioning, to keep students accountable for doing the homework. The remainder of the session is a dialogue focusing on the topics of the day, the instructor challenging each student on the subject matter in Socratic fashion, and also answering students’ questions. A second grade measures each student’s comprehension of the subject matter by the end of the session.

This format also works via teleconferencing, for students unable to attend a face-to-face session on campus.

#### Large sessions

Students meet with instructors in a standard classroom (normal class size and period length). Each of these sessions begins with a 10 minute graded quiz (closed-book) on the homework topic(s), to keep students accountable for doing the homework. Students may leave the session as soon as they “check off” with the instructor in a Socratic dialogue as described above (instructor challenging each student to assess their comprehension, answering questions, and grading the responses). Students sign up for check-off on the whiteboard when they are ready, typically in groups of no more than 4. Alternatively, the bulk of the class session may be spent answering student questions in small groups, followed by another graded quiz at the end.

#### Correspondence

This format works for students unable to attend a “face-to-face” session, and who must correspond with the instructor via email or other asynchronous medium. Each student submits a thorough presentation of their completed homework, which the instructor grades for completeness and accuracy. The instructor then replies back to the student with challenge questions, and also answers questions the student may have. As with the previous formats, the student receives another grade assessing their comprehension of the subject matter by the close of the correspondence dialogue.

## Methods of instruction (continued)

In all formats, students are held accountable for completion of their homework, “completion” being defined as successfully interpreting the given information from source material (e.g. accurate outlines of reading or video assignments) and constructive effort to solve given problems. It must be understood in an inverted learning environment that students *will* have legitimate questions following a homework assignment, and that it is therefore unreasonable to expect mastery of the assigned subject matter. What is reasonable to expect from each and every student is a basic outline of the source material (reading or video assignments) complete with major terms defined and major concepts identified, plus a good-faith effort to solve every problem. Question 0 (contained in every worksheet) lists multiple strategies for effective study and problem-solving.

### Sample rubric for pre-assessments

- **No credit** = Any homework question unattempted (i.e. no effort shown on one or more questions); incomprehensible writing; failure to follow clear instruction(s)
- **Half credit** = Misconception(s) on any major topic explained in the assigned reading; answers shown with no supporting work; verbatim copying of text rather than written in student’s own words; outline missing important topic(s); unable to explain the outline or solution methods represented in written work
- **Full credit** = Every homework question answered, with any points of confusion clearly articulated; all important concepts from reading assignments accurately expressed in the outline and clearly articulated when called upon by the instructor to explain

*The minimum expectation at the start of every student-instructor session is that all students have made a good-faith effort to complete 100% of their assigned homework. This does not necessarily mean all answers will be correct, or that all concepts are fully understood, because one of the purposes of the meeting between students and instructor is to correct remaining misconceptions and answer students’ questions. However, experience has shown that without accountability for the homework, a substantial number of students will not put forth their best effort and that this compromises the whole learning process. Full credit is reserved for good-faith effort, where each student thoughtfully applies the study and problem-solving recommendations given to them (see Question 0).*

### Sample rubric for post-assessments

- **No credit** = Failure to comprehend one or more key concepts; failure to apply logical reasoning to the solution of problem(s); no contribution to the dialogue
- **Half credit** = Some misconceptions persist by the close of the session; problem-solving is inconsistent; limited contribution to the dialogue
- **Full credit** = Socratic queries answered thoughtfully; effective reasoning applied to problems; ideas communicated clearly and accurately; responds intelligently to questions and statements made by others in the session; adds new ideas and perspectives

*The minimum expectation is that each and every student engages with the instructor and with fellow students during the Socratic session: posing intelligent questions of their own, explaining their reasoning when challenged, and otherwise positively contributing to the discussion. Passive observation and listening is not an option here – every student must be an active participant, contributing something original to every dialogue. If a student is confused about any concept or solution, it is their responsibility to ask questions and seek resolution.*

## Methods of instruction (continued)

If a student happens to be absent for a scheduled class session and is therefore unable to be assessed on that day's study, they may schedule a time with the instructor to demonstrate their comprehension at some later date (before the end of the quarter when grades must be submitted). These same standards of performance apply equally make-up assessments: either inspection of homework or a closed-book quiz for the pre-assessment, and either a Socratic dialogue with the instructor or another closed-book quiz for the post-assessment.

## Methods of instruction (continued)

### Lab sessions

In the lab portion of each course, students work in teams to install, configure, document, calibrate, and troubleshoot working instrument loop systems. Each lab exercise focuses on a different type of instrument, with a limited time period typically for completion. An ordinary lab session might look like this:

- (1) Start of practical (lab) session: announcements and planning
  - (a) The instructor makes general announcements to all students
  - (b) The instructor works with team to plan that day's goals, making sure each team member has a clear idea of what they should accomplish
- (2) Teams work on lab unit completion according to recommended schedule:
  - (First day) Select and bench-test instrument(s), complete prototype sketch of project
  - (One day) Connect instrument(s) into a complete loop
  - (One day) Each team member drafts their own loop documentation, inspection done as a team (with instructor)
  - (One or two days) Each team member calibrates/configures the instrument(s)
  - (Remaining days, up to last) Each team member troubleshoots the instrument loop
- (3) End of practical (lab) session: debriefing where each team reports on their work to the whole class

### Troubleshooting assessments must meet the following guidelines:

- Troubleshooting must be performed *on a system the student did not build themselves*. This forces students to rely on another team's documentation rather than their own memory of how the system was built.
- Each student must individually demonstrate proper troubleshooting technique.
- Simply finding the fault is not good enough. Each student must consistently demonstrate sound reasoning while troubleshooting.
- If a student fails to properly diagnose the system fault, they must attempt (as many times as necessary) with different scenarios until they do, reviewing any mistakes with the instructor after each failed attempt.

**How to get the most out of academic reading:**

- Outline, don't highlight! Identify every major idea presented in the text, and express these ideas in your own words. A suggested ratio is one sentence of your own thoughts per paragraph of text read.
- Articulate your thoughts as you read (i.e. "have a conversation" with the author). This will develop *metacognition*: active supervision of your own thoughts. Note points of agreement, disagreement, confusion, epiphanies, and connections between different concepts or applications.
- Work through all mathematical exercises shown within the text, to ensure you understand all the steps.
- Imagine explaining concepts you've just learned to someone else. Teaching forces you to distill concepts to their essence, thereby clarifying those concepts, revealing assumptions, and exposing misconceptions. Your goal is to create the simplest explanation that is still technically accurate.
- Create your own questions based on what you read, as a teacher would to challenge students.

**How to effectively problem-solve and troubleshoot:**

- Rely on principles, not procedures. Don't be satisfied with memorizing steps – learn *why* those steps work. Each step should make logical sense and have real-world meaning to you.
- Sketch a diagram to help visualize the problem. Sketch a graph showing how variables relate. When building a real system, always prototype it on paper and analyze its function *before* constructing it.
- Identify what it is you need to solve, identify all relevant data, identify all units of measurement, identify any general principles or formulae linking the given information to the solution, and then identify any "missing pieces" to a solution. Annotate all diagrams with this data.
- Perform "thought experiments" to explore the effects of different conditions for theoretical problems. When troubleshooting, perform *diagnostic tests* rather than just visually inspect for faults.
- Simplify the problem and solve that simplified problem to identify strategies applicable to the original problem (e.g. change quantitative to qualitative, or visa-versa; substitute easier numerical values; eliminate confusing details; add details to eliminate unknowns; consider simple limiting cases; apply an analogy). Remove components from a malfunctioning system to simplify it and better identify the nature and location of the problem.
- Check for exceptions – does your solution work for *all* conditions and criteria?
- Work "backward" from a hypothetical solution to a new set of given conditions.

**How to manage your time:**

- Avoid procrastination. Work now and play later, every single day.
- Consider the place you're in when deciding what to do. If there is project work to do and you have access to the lab, do that work and not something that could be done elsewhere (e.g. homework).
- Eliminate distractions. Kill your television and video games. Turn off your mobile phone, or just leave it at home. Study in places where you can concentrate, like the Library.
- Use your "in between" time productively. Don't leave campus for lunch. Arrive to school early. If you finish your assigned work early, begin working on the next assignment.

**Above all, cultivate persistence,** as this is necessary to master anything non-trivial. The keys to persistence are (1) having the desire to achieve that mastery, and (2) realizing challenges are normal and not an indication of something gone wrong. A common error is to equate *easy* with *effective*: students often believe learning should be easy if everything is done right. The truth is that mastery never comes easy!

file question0



## Checklist when reading an instructional text

*“Reading maketh a full man; conference a ready man; and writing an exact man”* – Francis Bacon

Francis Bacon’s advice is a blueprint for effective education: reading provides the learner with knowledge, writing focuses the learner’s thoughts, and critical dialogue equips the learner to confidently communicate and apply their learning. Independent acquisition and application of knowledge is a powerful skill, well worth the effort to cultivate. To this end, students should read these educational resources closely, write their own outline and reflections on the reading, and discuss in detail their findings with classmates and instructor(s). You should be able to do all of the following after reading any instructional text:

Briefly **OUTLINE THE TEXT**, as though you were writing a detailed Table of Contents. Feel free to rearrange the order if it makes more sense that way. Prepare to articulate these points in detail and to answer questions from your classmates and instructor. Outlining is a good self-test of thorough reading because you cannot outline what you have not read or do not comprehend.

Demonstrate **ACTIVE READING STRATEGIES**, including verbalizing your impressions as you read, simplifying long passages to convey the same ideas using fewer words, annotating text and illustrations with your own interpretations, working through mathematical examples shown in the text, cross-referencing passages with relevant illustrations and/or other passages, identifying problem-solving strategies applied by the author, etc. Technical reading is a special case of problem-solving, and so these strategies work precisely because they help solve any problem: paying attention to your own thoughts (metacognition), eliminating unnecessary complexities, identifying what makes sense, paying close attention to details, drawing connections between separated facts, and noting the successful strategies of others.

Identify **IMPORTANT THEMES**, especially **GENERAL LAWS** and **PRINCIPLES**, expounded in the text and express them in the simplest of terms as though you were teaching an intelligent child. This emphasizes connections between related topics and develops your ability to communicate complex ideas to anyone.

Form **YOUR OWN QUESTIONS** based on the reading, and then pose them to your instructor and classmates for their consideration. Anticipate both correct and incorrect answers, the incorrect answer(s) assuming one or more plausible misconceptions. This helps you view the subject from different perspectives to grasp it more fully.

Devise **EXPERIMENTS** to test claims presented in the reading, or to disprove misconceptions. Predict possible outcomes of these experiments, and evaluate their meanings: what result(s) would confirm, and what would constitute disproof? Running mental simulations and evaluating results is essential to scientific and diagnostic reasoning.

Specifically identify any points you found **CONFUSING**. The reason for doing this is to help diagnose misconceptions and overcome barriers to learning.

## General challenges following a tutorial reading assignment

- Summarize as much of the text as you can in one paragraph of your own words. A helpful strategy is to explain ideas as you would for an intelligent child: as simple as you can without compromising too much accuracy.
- Simplify a particular section of the text, for example a paragraph or even a single sentence, so as to capture the same fundamental idea in fewer words.
- Where did the text make the most sense to you? What was it about the text's presentation that made it clear?
- Identify where it might be easy for someone to misunderstand the text, and explain why you think it could be confusing.
- Identify any new concept(s) presented in the text, and explain in your own words.
- Identify any familiar concept(s) such as physical laws or principles applied or referenced in the text.
- Devise a proof of concept experiment demonstrating an important principle, physical law, or technical innovation represented in the text.
- Devise an experiment to disprove a plausible misconception.
- Did the text reveal any misconceptions you might have harbored? If so, describe the misconception(s) and the reason(s) why you now know them to be incorrect.
- Describe any useful problem-solving strategies applied in the text.
- Devise a question of your own to challenge a reader's comprehension of the text.

## General follow-up challenges for assigned problems

- Identify where any fundamental laws or principles apply to the solution of this problem.
- Describe in detail your own strategy for solving this problem. How did you identify and organized the given information? Did you sketch any diagrams to help frame the problem?
- Is there more than one way to solve this problem? Which method seems best to you?
- Show the work you did in solving this problem, even if the solution is incomplete or incorrect.
- What would you say was the most challenging part of this problem, and why was it so?
- Was any important information missing from the problem which you had to research or recall?
- Was there any extraneous information presented within this problem? If so, what was it and why did it not matter?
- Examine someone else's solution to identify where they applied fundamental laws or principles.
- Simplify the problem from its given form and show how to solve this simpler version of it. Examples include eliminating certain variables or conditions, altering values to simpler (usually whole) numbers, applying a limiting case (i.e. altering a variable to some extreme or ultimate value).
- For quantitative problems, identify the real-world meaning of all intermediate calculations: their units of measurement, where they fit into the scenario at hand.
- For quantitative problems, try approaching it qualitatively instead, thinking in terms of "increase" and "decrease" rather than definite values.
- For qualitative problems, try approaching it quantitatively instead, proposing simple numerical values for the variables.
- Were there any assumptions you made while solving this problem? Would your solution change if one of those assumptions were altered?
- Identify where it would be easy for someone to go astray in attempting to solve this problem.
- Formulate your own problem based on what you learned solving this one.

## How To . . .

**Access the worksheets and textbook:** go to the *Socratic Instrumentation* website located at <http://www.ibiblio.org/kuphaldt/socratic/sinst> to find worksheets for every 2nd-year course section organized by quarter, as well as both the latest “stable” and “development” versions of the *Lessons In Industrial Instrumentation* textbook. Download and save these documents to your computer.

**Maximize your learning:** complete all homework *before* class starts, ready to be assessed as described in the “Inverted Session Formats” pages. Use every minute of class and lab time productively. Follow all the tips outlined in “Question 0” as well as your instructor’s advice. Do not take constructive criticism personally. Make every reasonable effort to solve problems on your own before seeking help.

**Identify upcoming assignments and deadlines:** read the first page of each course worksheet.

**Relate course days to calendar dates:** reference the calendar spreadsheet file (`calendar.xlsx`), found on the BTC campus Y: network drive. A printed copy is posted in the Instrumentation classroom.

**Locate industry documents assigned for reading:** use the Instrumentation Reference provided by your instructor (on CD-ROM and on the BTC campus Y: network drive). There you will find a file named `00_index_OPEN_THIS_FILE.html` readable with any internet browser. Click on the “Quick-Start Links” to access assigned reading documents, organized per course, in the order they are assigned.

**Study for the exams:** Mastery exams assess specific skills critically important to your success, listed near the top of the front page of each course worksheet for your review. Familiarize yourself with this list and pay close attention when those topics appear in homework and practice problems. Proportional exams feature problems you haven’t seen before that are solvable using general principles learned throughout the current and previous courses, for which the only adequate preparation is independent problem-solving practice every day. Answer the “feedback questions” (practice exams) in each course section to hone your problem-solving skills, as these are similar in scope and complexity to proportional exams. Answer these feedback independently (i.e. no help from classmates) in order to most accurately assess your readiness.

**Calculate course grades:** download the “Course Grading Spreadsheet” (`grades_template.xlsx`) from the Socratic Instrumentation website, or from the BTC campus Y: network drive. Enter your quiz scores, test scores, lab scores, and attendance data into this Excel spreadsheet and it will calculate your course grade. You may compare your calculated grades against your instructors’ records at any time.

**Identify courses to register for:** read the “Sequence” page found in each worksheet.

**Receive extra instructor help:** ask during lab time, or during class time, or by appointment. Tony may be reached by email at [tony.kuphaldt@btc.edu](mailto:tony.kuphaldt@btc.edu) or by telephone at 360-752-8477.

**Identify job openings:** regularly monitor job-search websites. Set up informational interviews at workplaces you are interested in. Participate in jobshadows and internships. Apply to jobs long before graduation, as some employers take *months* to respond! Check your BTC email account daily for alerts.

**Impress employers:** sign the FERPA release form granting your instructors permission to share academic records, then make sure your performance is worth sharing. Document your project and problem-solving experiences for reference during interviews. Honor all your commitments.

**Begin your career:** participate in jobshadows and internships while in school to gain experience and references. Take the first Instrumentation job that pays the bills, and give that employer at least two years of good work to pay them back for the investment they have made in you. Employers look at delayed employment, as well as short employment spans, very negatively. Failure to pass a drug test is an immediate disqualifier, as is falsifying any information. Criminal records may also be a problem.

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### Question 1

Read the “Teaching Technical Theory” section of Appendix D (“How to Use This Book – Some Advice for Teachers”) in your *Lessons In Industrial Instrumentation* textbook. This will serve as the basis for a discussion on why the second-year Instrumentation courses are not lecture-based.

Imagine a child wishing to learn how to ride a bicycle. Seeking knowledge on the subject, the child approaches an adult asking for that adult to explain how to ride a bike. The adult responds with a detailed and thorough explanation of bicycle riding, including all the relevant safety rules. *After this explanation concludes, will the child be able to ride a bicycle?* Now imagine that same child reading a book on bicycle riding. The book is well-written and filled with clear illustrations to aid understanding. *After finishing this book, will the child be able to ride a bicycle?* Now imagine that same child watching a demonstration video on bicycle riding. The video is professionally shot, with very clear views on technique. The actor in the video does a great job explaining all the important aspects of bicycle riding. *After watching the video in its entirety, will the child be able to ride a bicycle?*

It should be obvious at this point that there is more to learning how to ride a bicycle than merely being shown how to do so. Bike riding is a skill born of *practice*. Instruction may be *necessary* to learn how to ride a bicycle safely, but instruction in itself is not *sufficient* to learn how to ride a bicycle safely – you must actively attempt riding a bicycle before all the pieces of information come together such that you will be proficient. *What is it about bicycle riding that necessitates practice in order to learn?*

Now imagine someone wishing to learn how to write poetry. Seeking knowledge on the subject, this person consults poets for advice, reads books of poetry and books about writing poetry, and even listens to audio recordings of poets presenting their work in public. *After all this instruction and research, will the person be a proficient poet?*

Here we have the same problem we had with learning to ride a bicycle: instruction may be a *necessary* part of learning to write poems, but instruction in itself is not *sufficient* to become a poet. One must actively write their own poems to become good at it. *What is it about poetry that necessitates practice in order to learn how to write it?*

The fundamental principle here is that *we master that which we practice*, because the brain strengthens neural pathways through repeated use. There is nothing unique about bicycle riding or poetry in this regard: if you wish to master any skill you must repeatedly *do* that skill. The problem with learning about bicycle-riding or poetry from other people is that you aren’t *doing* any bicycle riding or poetry yourself. The most valuable assistance any learner can receive is prompt and constructive feedback during the learner’s practice. Think of a child attempting to ride a bicycle with an adult present to observe and give practical advice; or of a person learning poetry, submitting their poems to an audience for review and then considering that feedback before writing their next poem.

When we research which skills are most valuable to instrument technicians, we find *self-directed learning* and *general problem-solving* top the list. These skills, like any other, require intensive practice to master. Furthermore, that practice will be optimized with prompt and expert feedback. In order to optimally prepare students to become instrument technicians, then, those students must be challenged to learn on their own and to individually solve problems, with the instructor coaching them on both activities.

Here is where schools tend to cheat students: the majority of class time is spent presenting information to students, rather than giving students opportunity to practice their problem-solving skills. This is primarily the consequence of *lecture* being the dominant mode of teaching, where a live instructor must spend hour upon hour verbally presenting information to students, leaving little or no time for those students to solve problems and sharpen their critical thinking skills. Assigned homework does a poor job of providing practice because the student doesn’t receive detailed feedback on their problem-solving strategies, and also because many students cheat themselves by receiving inappropriate help from their classmates. Furthermore, lecture is the antithesis of self-directed learning, being entirely directed by a subject matter expert. The skills practiced by students during a lecture (e.g. taking dictation on lengthy presentations) have little value in the career of an instrument technician. More time in school could be spent practicing more relevant skills,

but only if some other mode of instruction replaces lecture.

Not only does lecture displace more valuable activities in the classroom, but lecture isn't even that good of an instructional technique. Among the serious shortcomings of lecture are the following:

- Students' attentions tend to drift over the span of any lecture of significant length.
- Lecture works well to communicate facts and procedures but fails at getting students to think for themselves, because the focus and pace of any lecture is set by the lecturer and not the students.
- Lecture instills a false sense of confidence in students, because complex tasks always look easier than they are when you watch an expert do it without trying it yourself. (An oft-heard quote from students in lecture-based classes: "*I understand things perfectly during lecture, but for some reason I just can't seem to do the homework on my own!*")
- A lecturer cannot customize ("differentiate") instruction for individual students. Rather, everyone gets the exact same presentation (e.g. the same examples, the same pace) regardless of their diverse needs. The pace of lecture is perhaps the most obvious example of this problem: since the lecturer can only present at one pace, he or she is guaranteed to bore some students by going too slow for them and/or lose others by going too fast for them.
- Students cannot "rewind" a portion of lecture they would like to have repeated without asking the entire class to repeat as well.
- Students' must simultaneously dictate notes while trying to watch *and* listen *and* think along with the instructor, a difficult task at best. Multitasking is possible only for simple tasks where intense focus is not required.
- If the instructor commits some form of verbal error and doesn't realize it (which is very common because it's difficult to simultaneously present and self-evaluate), it is incumbent upon the students to identify the error and ask for clarification.
- The instructor cannot accurately perceive how each and every student is understanding the presentation, because the instructor is too busy presenting. Body language during the lecture isn't a reliable enough indicator of student understanding, and the time taken by lecture precludes the instructor visiting every student to inspect their work.
- Lecture instills an attitude of dependence by reinforcing the notion that personal consultation with an expert is necessary in order to learn anything new. This discourages people from even trying to learn complex things on their own. An all-too-common workplace example of this attitude is where employees believe they cannot learn new things unless they receive formal training.

For these reasons – the fact that lecture displaces class time better spent coaching students to solve problems, as well as the many problems of lecture as an instructional mode – there is almost no lecture in any of the 200-level Instrumentation courses at BTC. Instead, students learn the basic facts and procedures of the subject matter through reading assignments prior to class, then spend class time solving problems and demonstrating their understanding of each day's major topic(s) before leaving. This is called an *inverted classroom* because the classroom and homework roles are swapped: what is traditionally lectured on in class is instead done on the students' time outside of class, while the problem-solving traditionally done as homework is instead completed during class time while the instructor is available to coach. This format is highly effective not only for learning the basic concepts of instrumentation, but also for improving technical reading and critical thinking skills, simply because *it requires students to practice the precise skills they must master*.

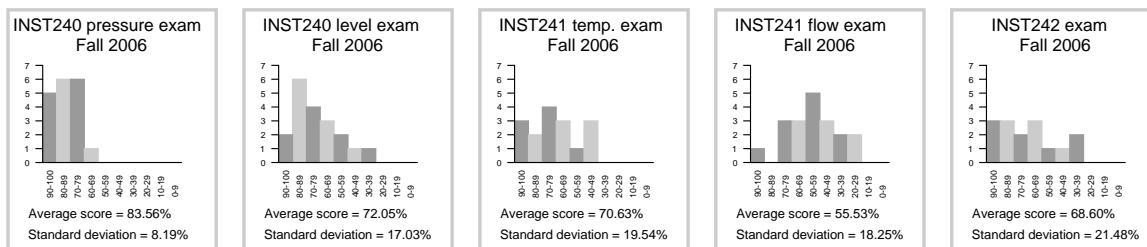
The primary reason *reading* was chosen as the preferred mode of instruction is feedback from employers as well as observations of student behavior, both sources revealing an aversion to technical reading. Some employers (most notably those who include reading comprehension within their pre-employment exams) noted in past years that reading comprehension was the weakest area when testing BTC students during past recruiting trips. Also, a failure to reference equipment manuals when working on real systems is a chronic problem both for novice technicians in a wide range of industries as well as students learning in a lab environment. Given the fact that far more high-quality technical literature is available in this career than

high-quality videos, reading comprehension is a vital skill for technicians to keep their knowledge up to date as technology advances.

Prior to 2006 all 200-level Instrumentation courses were strictly taught by lecture. Making matters worse, many of the courses had no textbook, and homework was seldom assigned. All 200-level exams prioritized rote memorization and execution of procedural problem-solving over creative problem-solving and synthesis of multiple concepts. It was common for second-year students to flounder when presented with a new piece of equipment or a new type of problem, because no instructor can teach procedures to cover any and all possible challenges.

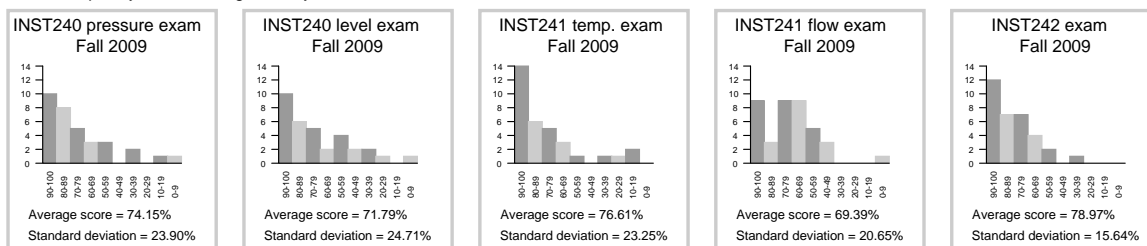
Since 2006 the 200-level Instrumentation courses have gradually morphed from lecture to “inverted” format, with measurable gains in learning. Proportional exam scores from the Fall quarter courses (INST240, INST241, and INST242 – those courses where the content has remained most stable over this time span) demonstrate this, each histogram showing the number of students (vertical axis) achieving a certain exam score (horizontal axis):

Fall 2006: limited text resources for students (no standard textbook for the curriculum), classroom format a mixture of lecture and group discussion



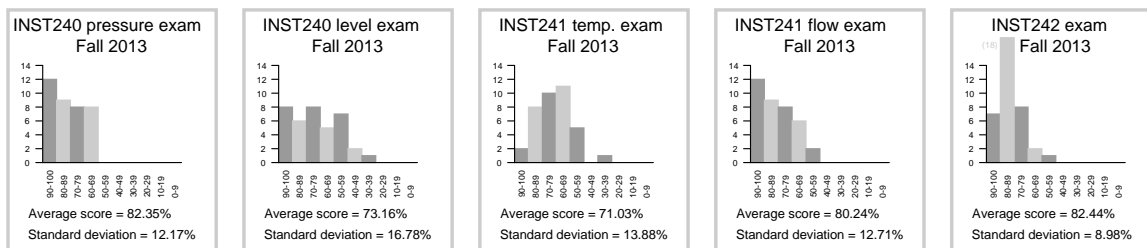
Cumulative exam score average for Fall quarter 2006 = 70.07%  
 Cumulative exam score standard deviation for Fall 2006 = 19.27%

Fall 2009: *Lessons In Industrial Instrumentation* textbook available to students, classroom format still a mixture of lecture and group discussion  
 Exam complexity increased significantly since the introduction of the new textbook in 2008



Cumulative exam score average for Fall quarter 2009 = 74.18%  
 Cumulative exam score standard deviation for Fall 2009 = 21.88%

Fall 2013: *Lessons in Industrial Instrumentation* textbook greatly expanded, classroom format fully inverted (i.e. no lecture)  
 Mastery exam complexity increased since 2009, requiring broader competence and leaving less time to complete proportional exams



Cumulative exam score average for Fall quarter 2013 = 77.85%  
 Cumulative exam score standard deviation for Fall 2013 = 13.89%

Note the general improvement in average exam scores (2009) toward the end of the quarter, despite the exams being more complex than they were in 2006. Students were held accountable for the assigned



textbook reading with graded “prep quizzes” at the beginning of each class session. Note also how the standard deviations increased, representing a greater degree of “spread” between student performance on these exams. The increased standard deviation shows some students falling behind their peers, since lecture was not providing for their needs with a more challenging curriculum.

In the third set of histograms (2013) we see general increases in average scores as well as marked improvements in standard deviation across the board (showing fewer students “left behind” their peers). The inverted classroom format allows the instructor to spend one-on-one time with each and every student to probe for misconceptions and offer assistance when needed. This kind of differentiated instruction is impossible in a lecture format. Even more remarkable is the fact that the exam complexity increased since 2009, with longer mastery exams (reviewing concepts from previous courses including first-year circuit principles) and more complex proportional exams. In 2013 the exams so fully exhausted the 3-hour testing period that graded results could no longer be given before the end of the day, and instead had to wait until the following day. Yet, despite this increased rigor exam scores increased and standard deviation narrowed.

One of the most striking improvements realized since abandoning lecture is the ease of which students grasp some of the more complex concepts throughout the year. These concepts used to be difficult to convey in a lecture format (mostly due to pacing problems, since different students would get “stuck” at different points in the presentation), and so long as some lecture existed in the classroom students would tend to give up when they encountered difficult concepts in the assigned reading (knowing they could rely on the instructor to lecture on these tough concepts in class):

- INST230 course: Three-phase electric power system calculations
- INST230 course: Normally-open versus normally-closed contact status
- INST240 course: Interface liquid level measurement (hydrostatic and displacer)
- INST240/250 courses: Force-balance versus motion-balance pneumatic mechanisms
- INST241 course: Coriolis mass flowmeters
- INST242 course: Gas chromatograph operation
  - Not only are students able to fully grasp basic GC operation in only one day, but they are also able to tackle multi-column GCs as well!
- INST242 course: Non-dispersive optical analyzers (NDIR, Luft detectors, etc.)
  - Comprehension of this topic used to be a real struggle, with a good percentage of students failing to grasp filter cells and Luft detectors by the end of the first day. Now this concept comes easily to all in one day.
- INST250 course: Fluid power system analysis (hydraulic and pneumatic diagrams)
- INST250 course: Split-ranged control valve sequencing
- INST250 course: Control valve characterization
  - Comprehension of this topic is so much better now that I’ve had to modify that day’s learning activities to provide more challenge than in past years.
- INST252/263 courses: Feedforward control strategies
  - Dynamic compensation in particular used to be such a struggle to teach that most students really didn’t seem to “get” the concept after repeated explanations. Now it’s no more challenging than any other control concept we tackle in the program.
- INST252 course: Loop stability analysis (based on trend recordings)
- INST260 course: Data acquisition hardware connections (e.g. differential vs. single-ended connections)
- INST262 course: FOUNDATION Fieldbus and wireless (radio) digital communications
  - The first year I taught FOUNDATION Fieldbus using an inverted classroom, my students knew the topic better than our guest lecturer who I invited to present on the subject! The students’ only exposure to FOUNDATION Fieldbus at that point was one night’s study prior to the guest’s appearance.
- INST263 course: Selector and override controls

This improvement in student learning has been verified by industry representatives, when they are invited to come to BTC to review certain complex topics such as Fieldbus, WirelessHART, and control valves. The general feedback they give is that BTC students are unusually well-prepared on these subjects. The “secret” of course is that students learning in an inverted classroom format spend more time immersed

in the subject matter, and the feedback they receive from their instructors in class is better tailored to their individual learning needs.

Feedback I have received from graduates since learning in a lecture-free environment is that they are much more comfortable with learning on their own than before, and that this skill has served them well during the job-search process. Students who embraced the “inverted” instructional format have no problem at all researching an employer’s background, identifying desired knowledge and skills from job descriptions, and then preparing themselves for interviews where they will be queried on those knowledge and skill domains.

Another significant gain realized since abandoning lecture is the immediate placement of inexperienced BTC Instrumentation graduates in jobs typically reserved for engineers with 4-year degrees. This simply did not happen when BTC’s Instrumentation program was lecture-based, and it is due to the fact that students explicitly learn higher-order thinking skills when they must gather information on their own outside of class and then demonstrate critical thinking before an instructor every day. This has happened once in December 2011, again in December 2012, again in March 2013, and again in August 2013.

Yet, despite the gains realized by abandoning lecture in favor of an “inverted” teaching format, some students are highly resistant to the concept. Some of the critical comments routinely heard from students against the inverted format are as follows:

- (1) *“I learn better in a lecture format.”*
- (2) *“My learning style is visual, which means I need to see someone solve the problems for me.”*
- (3) *“When I arrive to class after doing the assigned reading and trying to solve the homework problems, I’m completely lost.”*

Discuss each of these comments in detail. Here are some starting points for conversation:

- (1) What does it mean to learn something *better*? How may a student measure how well they’ve learned something new? What, exactly, is it that is learned better in lecture? Is there anything significant that students *don’t* learn in a lecture?
- (2) Would someone with an *auditory* or *kinesthetic* learning style fare any better in an inverted classroom? Does a visual learning style preclude effective reading, or independent learning? Are learning styles real or merely perceived? Are learning styles immutable (i.e. permanent), or is it possible for people to cultivate new learning styles?
- (3) Define “lost” – does this mean absolutely *nothing* made sense, or are there specific points that did not make sense? Did the reading seem to make sense before attempting the homework problems, or did the confusion begin during the reading process? What does it mean if a student is lost after completing the homework for an inverted class, assuming a significant number of their classmates are *not* lost? What would be an appropriate course of action to take in response to this condition?

file i00004

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## Question 2

You may find the course structure and format of the INST courses to be quite different from what you have experienced elsewhere in your education. For each of the following examples, discuss and explain the rationale. What do you think is the greater purpose for each of these course standards and policies?

- Homework consists of studying new subjects prior to arriving to class for the theory sessions. Students' primary source of new information is in the form of written materials: textbooks, reports, and manufacturer's literature. Daily quizzes at the start of each class session hold students accountable for this preparatory learning. *Why study new subjects outside of class, instead of doing normal homework that reviews subjects previously covered in class? Why the strong emphasis on reading as a mode of learning?*
- Classroom sessions are not lecture-oriented. Rather, classroom sessions place students in an active role discussing, questioning, and investigating what they're learned from their independent studies. Learning new facts (knowledge) and how to interpret them (comprehension) is the students' responsibility, and it happens before class rather than during class. Class time is devoted to higher-level thinking (application, analysis, synthesis, and evaluation). *What's wrong with lecture, especially when the overwhelming majority of classes in the world are taught this way?*
- Students are expected to track their own academic progress using a computer spreadsheet to calculate their own course grades as they progress through each school quarter. *Why not simply present the grades to students?*
- Students must explicitly apply "sick hours" to their absences (this is not automatically done by the instructor!), and seek donations from classmates if they exceed their allotment for a quarter. *Why not simply allow a fixed number of permitted absence for each student, or let the instructor judge the merits of each student's absence on a case-by-case basis?*
- Mastery exams, where students must answer all questions with 100% accuracy. *What's wrong with regular exams, where a certain minimum percentage of correct answers is all that's necessary to pass?*
- Students may submit optional, ungraded assignments called "feedback questions" to the instructor at the end of most course sections in order to check their preparedness for the higher-level thinking challenges of the upcoming exam. *Why in the world would anyone do work that doesn't contribute to their grade?*
- Troubleshooting exercises in lab and diagnostic questions in homework, where students must demonstrate sound reasoning in addition to properly identifying the problem(s). *Isn't it enough that the student simply finds the fault?*
- Extra credit is offered for students wishing to improve their grades, but this extra credit is always in the form of practical and realistic work relevant to the specific course in which the extra credit is desired. *Why doesn't unrelated work count?*

[file i03484](#)

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Question 3

Explain the difference between a *mastery* assessment and a *proportional-graded* assessment. Given examples of each in the course(s) you are taking.

file i00113

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Question 4

Read “The Lecture System In Teaching Science” by Robert T. Morrison, an article from the Journal *Undergraduate Education In Chemistry and Physics*, October 18-19, 1985, pages 50 through 58. This article is available in electronic form from the BTC campus library, as well as on the Internet (easily found by performing a search). In it, Morrison outlines a teaching method referred to as the “Gutenberg Method.”

How is the Gutenberg Method as described by Morrison similar to the classroom structure in these Instrumentation courses?

Identify in your own words at least two advantages the Gutenberg Method enjoys over standard lectures.

Explain how a person educated in this way might be better prepared for continuing education in the workplace, compared to those who learned by lecture while in school.

file i00008

## Answers

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Answer 1

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Answer 2

The general philosophy of education in these courses may be summed up in a proverb:

**“Give a man a fish and you feed him for a day. Give a man a fishing pole and you feed him for life.”**

Instrumentation is a highly complex, fast-changing career field. You will not survive, much less thrive, in this field if all you can ever learn is what someone directly teaches you. In order to stay up-to-date with new technology, figure out solutions to novel problems, and adapt to a changing profession, you absolutely *must* possess independent learning ability. You must be able to “fish” for new knowledge and understanding on your own. These courses are designed to foster this higher-level skill.

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Answer 3

A *mastery* assessment is one that must be passed with a 100% score (no errors). Mastery assessments are usually given with multiple opportunities to pass. The basic idea is, you try and try until you get it perfect. This ensures mastery of the concept, hence the name.

By contrast, a *proportional-graded* assessment is one where you do not have to achieve perfection to pass. Most of the tests and assignments you have completed in your life are of this type. A grade (percentage, ranking, and/or letter) is given based on how well you answer the question(s).

In all the Instrumentation courses, all exams have both mastery and proportional sections. Lab exercises likewise have both mastery and proportional sections as well. Preparation and feedback grades are strictly proportional, with no mastery component.

Follow-up question: what happens if you fail to fulfill a mastery assessment within the allotted time?

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Answer 4

This is a graded question – no answers or hints given!