Portfolio-based Assessment in STEM

STEM-TEC Seminar – 15 October 2020

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Motivation

- STEM subjects are challenging to many students
- Declining enrolments
- High attrition
- Students are diverse in
  - prior knowledge,
  - experience, and
  - learning approaches

Alternative methods of teaching and assessment should be investigated

Theory

Constructive learning theory

- More than merely accommodate the diversity of the student cohort
- Rather, try to integrate student uniqueness into the learning process
- The student
    - is responsible for learning
    - is actively involved in the learning process
    - creates and discovers knowledge
    - sustains motivation by building confidence

Constructive learning theory

- The instructor
  - facilitates learning
  - helps the student to get to their own understanding

Constructive Alignment

- Students construct meaning from **what they do to learn**
- Instructors align planned learning activities and learning outcomes
  - provide students with clearly specified goals
  - well-designed and appropriate learning activities
  - well-designed assessment criteria for **providing feedback**

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Focusing on learning through constructive alignment with task-oriented portfolio assessment

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ABSTRACT
Approaches to learning have been shown to have a significant impact on student success in technical units. This paper reports on an action research study that applied the principles of constructive alignment to improve student learning outcomes in programming units. The proposed model uses frequent formative feedback to engage students with unit material, and encourage them to adopt deep approaches to learning. Our results provide a set of guiding principles and a structured teaching approach that focuses students on meeting unit learning objectives, the goal of constructive alignment. The results are demonstrated via descriptions of the resulting teaching and learning environment, student results, and staff and student reflections.

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KEYWORDS
Constructive alignment; assessment of learning outcomes; formative feedback; portfolio assessment

Task-Oriented Portfolio Assessment

- frequent formative feedback
- encourage the adoption of deep approaches to learning
- development of approach and implementation led by Andrew Cain

Some Opposing Realities

- Lecture halls do not physically accommodate student-led discussion
- Students expect lectures
  - “I did not pay $$$$ in tuition to hear what other students think”
- Students (and exam boards) expect grades
  - no room for qualitative assessment of a student’s learning journey

Assessment

- Shift focus away from marking
  - Marking = deducting points for errors and omissions
- Shift focus toward supporting learning
  - Formative assessment = constructive feedback
- To first order, final grade is determined by **what students do**
  - what is done demonstrates depth of learning
- Refinement of final grade depends on quality of submitted work, level of engagement, etc.

Formative Assessment

- students pay more careful attention to feedback when there are no associated marks (Black and Wiliam 1998)
- feedback on graded tasks is not seen as formative, but rather as providing justification for the marks received (Skinner 2014)
- by removing marks from assessment, both staff and students work together to help students achieve learning outcomes (Cain et al. 2018)

Practice (General)

First-order Assessment

- Demonstrated level of learning corresponds to level of achievement
  - Pass (C- to C+) – ability to retain knowledge, understand concepts, and apply knowledge to solve problems
  - Merit (B- to B+) – ability to analyze a problem, select appropriate methods, and synthesize ideas
  - Distinction (A- to A+) – ability to evaluate an argument, test a hypothesis, and design and create original work

Learning Activities

- **What students do** demonstrates level of learning
- Activities structured around grade outcomes
- Higher grade tasks require the demonstration of greater depth of understanding

Learning Activities – Pass

- Pass (C- to C+) – ability to retain knowledge, understand concepts, and apply knowledge to solve problems
- Students complete weekly "pass tasks"
  - designed to build core competencies
  - extensive instructions and support from teaching team
  - demonstrate minimal acceptable standard of understanding
- Students submit completed work with reflection on learning
  - students relate activity to intended learning outcomes

Learning Activities – Merit

- Merit (B- to B+) – ability to analyze a problem, select appropriate methods, and synthesize ideas
- Students complete one or two “merit assignments”
  - independent problem solving
  - demonstrate a greater depth of understanding
- Assignment problems designed to require analysis and
  - identification of relevant concepts and techniques
  - drawing connections between different concepts

Learning Activities – Distinction

- Distinction (A- to A+) – ability to evaluate an argument, test a hypothesis, and design and create original work
- Students complete an independent research project
  - students choose topic and design project
  - guidance is provided on structure, scope, and relevance
  - students submit proposal for review early in semester

Deadlines

- Ideal: support learning driven by student at their own pace
- Practical:
  - Students struggle with time management
  - Instructors struggle to assess a semester of effort in the final week
- Implementation:
  - Staged delivery of work for formative assessment
  - Final summative assessment of portfolio at end of semester

Example:

Object-oriented Programming

Learning Objectives

- Explain the principles of the object oriented programming paradigm specifically including abstraction, encapsulation, inheritance and polymorphism
- Use an object oriented programming language, and associated class libraries, to develop object oriented programs
- Design, develop, test, and debug programs using object oriented principles in conjuncture with an integrated development environment
- Construct appropriate diagrams and textual descriptions to communicate the static structure and dynamic behaviour of an object oriented solution
- Describe and explain the factors that contribute to a good object oriented solution, reflecting on your own experiences and drawing upon accepted good practices.

Learning Objectives

- Explain the principles of OOP:
  - abstraction, encapsulation, inheritance and polymorphism
- Use an OO language
- Design, develop, test, and debug programs using an IDE
- Use UML diagrams to describe a design
- Understand good OO design (e.g. design patterns)

Learning Activities – Pass

- Pass (C- to C+) – ability to retain knowledge, understand concepts, and apply knowledge to solve problems
- Students complete weekly “pass tasks”
  - each task forms the component of a larger program
  - given extensive instructions and support from teaching team
- By the end of the semester, student has a useable and interesting program (e.g. a simple adventure game)

Learning Activities – Merit

- Merit (B- to B+) – ability to analyze a problem, select appropriate methods, and synthesize ideas
- Students complete one or two "merit assignments"
  - choose from list of suggested extensions to the pass task program
  - little or no initial guidance or direction given on these tasks
  - independent problem solving
  - teaching staff available for support

Learning Activities – Distinction

- Distinction (A- to A+) – ability to evaluate an argument, test a hypothesis, and design and create original work
- Students complete an independent research project; e.g.
  - explore an OO language feature not already covered
  - run performance benchmarks that compare different algorithms
  - design and implement own program

Pros and Cons

- A lot can be done based on relatively few concepts / principles
  - Relatively complex program is achievable in one semester
  - Students can start early
- Most of the learning objectives are about **doing**
- Harder to detect plagiarism in software
  - Tools exist, but not off-the-shelf in Blackboard

Example:

Classical Mechanics and Thermodynamics

Learning Objectives

- Demonstrate understanding of the principles of mechanics and thermodynamics.
- Formulate and appreciate the fundamentals of Newtonian dynamics and statics.
- Understand and apply principles of physics and mathematical techniques to problem solving in mechanics and thermodynamics.

- Wide variety of concepts, principles, laws, and techniques
  - Algebra, geometry, calculus, vectors
  - Coordinate systems and relative motion
  - Kinematics (position, velocity, acceleration)
  - Dynamics (Newton’s laws: Force, mass, momentum)
  - Rotational kinematics (angular displacement, velocity, acceleration)
  - Rotational dynamics (Torque, moment of inertia, angular momentum)
  - Gravitation, Kepler’s Laws
  - Work, Energy, Temperature, Friction, Drag, Heat, Entropy
  - Ideal Gases and Thermodynamic Processes
  - First and Second Laws of Thermodynamics,
  - Engines, efficiency, Carnot cycles

Challenges

- Breadth of concepts hard to unite in a single project
- Challenging to
  - design a coherent set of pass tasks
  - avoid a series of isolated questions in merit assignments
  - Imagine/choose an independent project early in the semester

Activities – Pass Tasks

- Mostly united by a theme; e.g. aerospace
  - Projectile Motion with Air Resistance
  - Re-entering the Earth's Atmosphere
  - Ideal Rocket Equation
  - Hohmann Transfer Orbit
  - Equilibrium Temperature of a Satellite
  - Efficiency of a Jet Engine
- Most incorporate numerical simulations using MATLAB

Activities – Merit Assignments

- Place emphasis on problem-solving strategy
  - Conceptualise – draw a diagram
  - Categorise – list relevant concepts
  - Analyse – set up and solve equations
  - Finalise – perform sanity checks on answer
  - Reflect – relate activity to learning objectives
- Components of recommended strategy form the assessment criteria for most merit assignment problems

Activities – Distinction Projects

- Provided a list of project ideas
- Students mostly picked ideas related to first six weeks of topics
- Aim is to demonstrate critical thinking and analysis skills

Outcomes

Intro to Programming Student Feedback

- based on responses from 350 students
- Student satisfaction: 8.6 / 10
  - faculty mean: 7.5 and university mean: 7.6
- Clarity of assessment: 8.6 / 10
  - faculty and university mean: 7.7

Intro to Programming Student Feedback

- Best aspects of paper:
  - 16 student specifically mentioned clarity of assessment
  - 6 specifically noted feedback
  - 39 indicated the tasks and using these to develop understanding without needing marks

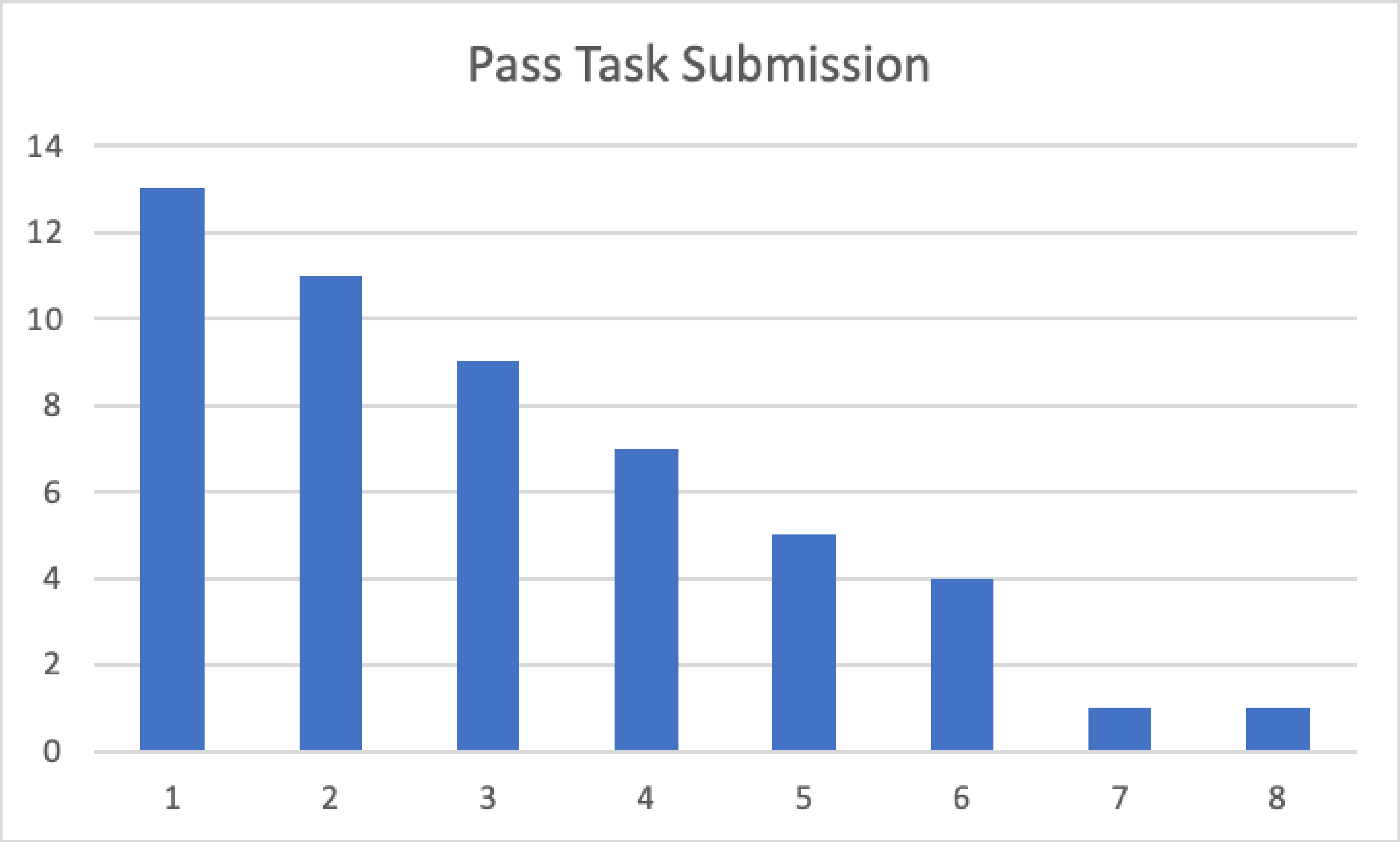
Physics – Engagement with Instruction

- Current semester; therefore, no student feedback
- Student engagement with instruction is very low
- 59 students enrolled
  - between 3 and 10 attend lectures
  - ~ 12 watch recorded lecture videos (Panopto)
  - ~ 10 attend tutorials

Physics – Engagement with Activities

- 59 students enrolled
- Student engagement with learning activities is very low
- 17 submitted distinction project proposals
- 28 submitted merit assignment 1
- 12 submitted merit assignment 2
- 13 submitted pass task 1 … declining linearly each week

Physics – Engagement with Weekly Tasks



Impact on Instructors

- Providing meaningful and constructive feedback is both time-consuming and more rewarding
- Tutors require more detailed guidance and support to participate effectively in formative assessment workflow
- To provide structured feedback, tutors require approximately double the usual time allocated for marking
- It is challenging to develop content (lectures, learning activities, and assessment guidelines) and support students in parallel

Conclusions

- Portfolio-based assessment works very well for an introductory programming subject
- So far, portfolio-based assessment does not appear to have improved the engagement of first-year physics students

Classical Mechanics and Thermodynamics	Object-oriented Programming
Challenging to unify concepts in a single project / theme	A single project can address all of the learning objectives
Varied reasons for studying physics	More uniform student objectives
Greater complexity (breadth of concepts and problem-solving techniques)	Smaller core of principles aimed at managing and reducing complexity through abstraction