# What Do CS1 Syllabi Reveal About Our Expectations of Introductory Programming Students?

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# Motivation

- "Learning to Program is Easy", ITiCSE 2016 paper by Andrew Luxton-Reilly
- Challenged the orthodox view that programming is hard to learn
- Proposed that the computing education community should view our learning outcomes for CS1 courses as being unrealistic
- Presented substantial evidence that this view has deeply permeated the computing education community's culture, literature and psyche
- Challenge to the community (next slide)

# Motivation

- Luxton-Reilly's challenge:

*Collect research-based evidence of what novice programmers can achieve in CS1, and use evidence to derive realistic expectations for achievement*

- Our overarching question, which we view as a prerequisite to meeting the above challenge:

***What exactly do we expect our introductory programming students to achieve?***

# Learning Outcome Statements

- This quickly led us to examining **learning outcome statements (LOs)**
- In Europe, LOs are the foundation for all courses and programmes (as per Bologna accord)
- Typically look like: “Upon completion of this course, students will be able to…”
- We refer to these as *explicit* learning outcomes
- It is possible (but a little risky) to *infer* LOs from a syllabus which doesn’t have explicit LOs, particularly if it contains aims, or other wording, beyond a bullet-list of topics

# Motivating Questions

- Q1: What percentage of CS1 courses have explicit learning outcomes?
- Q2: What concepts do explicit CS1 learning outcomes cover?
- Q3: How do These Concepts Align With CS2013?
- Q4: What do explicit CS1 learning outcomes look like?
- Q5: What is the current CS1 teaching language distribution?
- Q6: What are the most common computing terms found in CS1 syllabi?

# Motivating Viewpoints

In forming these questions, we aimed to provide information from three vantage-points:

1. **That of other educators**, by presenting information such as their explicit CS1 learning outcomes word for word, for further analysis/use by the community
2. **That of our tool**, by presenting derived information such as a list of concepts included in learning outcomes
3. **A somewhat agnostic view**, by including information such as full-syllabus word frequency counts.

# Method

- We manually curated CS1 syllabi by searching the websites of all 916 institutions making up the 2016-2017 QS World University Rankings
- Stored various information in a database:
  - URL
  - Learning outcomes (and if explicit)
  - Language(s)
  - Prerequisites
  - etc.
- Available at csed.ucd.ie/SIGCSE2019

# Method

- Found 234 CS1 courses from 207 institutions in 30 countries
- Problems:
  - 50% of syllabi from US institutions
  - More than 50% of syllabi from Anglophone countries
  - Other issues due to being from one list (biased towards QS ‘qualities’, etc.)
- However, this was time consuming, and this method gave us a good start
- Although biased, it provided a mechanism that hopefully did not introduce (too many of) our own biases

**Number of syllabi (#$S$) and institutions (#$I$) per country, and percent of total syllabi (%$T$), $n = 234$.**

| Country | #$S$ | #$I$ | %$T$ | Country | #$S$ | #$I$ | %$T$ |
|---|---|---|---|---|---|---|---|
| USA | 118 | 114 | 50 | India | 4 | 4 | 2 |
| England | 33 | 31 | 14 | South Africa | 3 | 3 | 1 |
| Australia | 15 | 15 | 6 | Turkey | 3 | 3 | 1 |
| Scotland | 9 | 8 | 4 | Portugal | 2 | 1 | 1 |
| Ireland | 8 | 5 | 3 | Sweden | 2 | 2 | 1 |
| Canada | 7 | 7 | 3 | Netherlands | 2 | 2 | 1 |
| New Zealand | 6 | 5 | 3 | Lebanon | 2 | 2 | 1 |
| Wales | 5 | 5 | 2 | | | | |
| China, Czech Republic, Denmark, Egypt, Ghana, Hungary, Jordan, Kenya, Pakistan, Philippines, Qatar, Singapore, South Korea, Switzerland and United Arab Emirates have 1 syllabus each (<1%). | | | | | | | |

# Results Q1: What percentage of CS1 courses have explicit learning outcomes?

- 66%
- We believe this is important, as explicit learning outcomes provide a direct mechanism to gauge the expectations we have for students, and are therefore central to Luxton-Reilly's challenge

# Results Q2: What concepts do explicit CS1 learning outcomes cover?

| Concept | Percentage of Courses | | |
|---|---|---|---|
| | Explicit | !Explicit | All |
| Testing & debugging | 56 | 28 | 45 |
| Writing programs | 55 | 30 | 46 |
| Selection statements (if/else,etc.) | 46 | 43 | 44 |
| Problem solving (including computational thinking terms) | 45 | 47 | 45 |
| Arrays, lists, vectors, etc. | 41 | 37 | 39 |
| Basic OOP | 40 | 32 | 36 |
| Variables, assignment, arithmetic operators, declarations, data types | 40 | 35 | 38 |
| Functions, methods, procedures | 38 | 25 | 33 |
| Repetition & loops | 37 | 29 | 34 |
| Designing algorithms | 29 | 37 | 31 |
| Classes & objects | 25 | 18 | 22 |
| File handling & I/O | 23 | 28 | 24 |
| Documentation | 21 | 11 | 17 |
| Recursion | 20 | 16 | 18 |
| Data structures (general or specific - e.g. stacks) | 19 | 30 | 23 |

# Results Q3: How do these concepts align with CS2013?

- CS2013 knowledge unit *Fundamental Programming Concepts*, in the *Software Development Fundamentals* knowledge area, covers 8/15 of the concepts on the previous slide
- Including the other three KUs in the SDF KA covers 13/15.
- Only two concepts not covered by SDF are Basic OOP and Classes & Objects
  - Not surprising  as SDF was intended to be paradigm-agnostic
  - These two concepts are covered by CS2013 KU *Object-Oriented Programming* in the KA *Programming Languages*

# Results Q4: What do Current CS1 Learning Outcomes Look Like?

- In the 154 syllabi with explicit LOs, we found 1,029 LOs
  - Average of just under 7 LOs / syllabus
- All available at csed.ucd.ie/SIGCSE2019

# Results Q5: What is the current CS1 teaching language distribution (in this data)?

CS1 teaching language distribution in this study $n = 152$, and Siegfried et al. (2012), $n = 356$.

| Language | This study (2016-17 data) Number of Courses | % | From [23] (2012) % |
|---|---|---|---|
| Java | 74 | **49** | 55 |
| Python | 36 | **24** | 12 |
| C++ | 30 | **20** | 23 |
| C | 8 | **5** | 5 |

Haskell, JavaScript and R appeared $\leq 1\%$ in both studies. We do not report languages appearing in [23] but not in our data such as Alice.

[23] Robert Michael Siegfried, Daniel Greco, Nicholas Miceli, and Jason Siegfried. 2012. Whatever happened to Richard Reid's list of first programming languages? Information Systems Education Journal 10, 4 (2012).

# Results Q6: What are the most common computing terms in CS1 syllabi?

| Term | Count | Term | Count |
|---|---|---|---|
| Programming | 1,384 | Class/es | 275 |
| Design | 627 | Assignment | 227 |
| Data | 520 | Object/s | 207 |
| Algorithm/ic/s | 410 | Web | 196 |
| Test/ing/s | 356 | Control | 181 |
| Method/s | 330 | Array/s | 175 |
| Function/s | 317 | Security | 175 |

This was tricky at times. For example does “assignment” refer to a learning task or assignment operator/statement?

We removed all occurrences of “assignment**s**” as this most likely does refer to learning tasks.

# A tool for the community

- csed.ucd.ie/sigcse2019
- Contains all of the data we collected, and used to generate our results
- All 234 syllabi we curated can be searched and sorted by language, location, if the learning outcomes are explicit, learning outcome concepts (including their counts from matching linked syllabi), and more
- Full dataset downloadable in JSON
- Educators can upload their own courses – these are viewable but stored with *submitted* tag so they can be separated from original data

Home | Syllabus Database | Download Collection | Information | Contribute Syllabus | Admin

Search specifications:

Language - Any | Location - Any | Explicit or Scraped LO | All sources | Submit

**13 results matching the specification: Java England Explicit**

Categories | Syllabi

| # | Location | Course Code | Course Title | University | Programming Language |
|---|---|---|---|---|---|
| 1 | England | COM1027 | Programming Fundamentals | University of Surrey | Java |
| 2 | England | CS4001 | Programming | London Metropolitan University | Java |
| 3 | England | Java 1 | Object Oriented Programming with Java Part 1 | City University of London | Java |
| 4 | England | COMP 1003 | Java Programming | University of Sheffield | Java |
| 5 | England | COMP 1011 | Introduction to Programming | Durham University | Java |
| 6 | England | COMP 1202 | Programming 1 | University of Southhampton | Java |
| 7 | England | | Programming (Java) | Manchester Metropolitan University | Java |
| 8 | England | CS 118 | Programming for Computer Scientists | The University of Warwick | Java |

# Threats to Validity

- All syllabi are from QS world rankings
  - There are several threats buried in here
- We could have missed some courses
- Although we focussed on concepts we didn't explore the depth to which they are covered
- More in paper

# Conclusions

- What do we expect of our introductory programming students?
  - This data can help start to answer that question
- We note that there is limited evidence on what we expect of our students on a large scale
  - This work demonstrates that gaining a representative picture of what we expect of our students fraught with biases and details that make gathering such evidence difficult
  - Nonetheless we think that the information we provide may be useful to the community
- It is probable that many syllabi are designed either by consulting model curricula or are inspired from other, more established syllabi at other universities
  - This aligns with Luxton-Reilly's claim that certain views have deeply permeated the computing education community's culture, literature and psyche

# Future Work

- Future work involves collecting more syllabi and analysing this data

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