

# Achieving Gender Balance through Creative Expression (in the arts)

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# Overview

- ▶ Gender balance can be achieved by providing opportunities for **creative expression throughout** the four years of an undergraduate computing degree.
- ▶ We present a four-course sequence combining computing and the arts that can serve as the core of a Computing in the Arts major or a concentration to **complement** an existing Computer Science major.
- ▶ A robust six-year longitudinal study shows that these courses attract, retain, and graduate **46% female students**, while the corresponding number in our ABET-accredited Computer Science curriculum is approximately **20%**.
- ▶ Concludes with observations and suggested directions for future action in CS curricula design.

# Gender Balance & Creativity

- **Problem:** The national graduation rate of female students in computer science is approximately 20% <sup>32, 36</sup>
- **Importance:** By not reaching so many people, society and the field of computing miss out on innovative ideas while millions of tech jobs go unfilled
- **Prior Solutions:** Contextualized computing and media computation courses<sup>17</sup>
- **Prior Successes:** Georgia Tech and University of Colorado report approximately 45% enrollments of women in their contextualized programs <sup>19, 5</sup>

32 Tims, J., Zweben, S., Timanovsky, Y. and Prey, J. ACM-NDC Study 2016–2017: Fifth Annual Study of Non-Doctoral-Granting Departments in Computing, *ACM Inroads*, 8(3), pp. 48-62.

36 Zweben, S. and Bizot, B. 2016 Taulbee Survey: Generation CS Continues to Produce Record Undergrad Enrollment; Graduate Degree Production Rises at both Master's and Doctoral Levels, Computing Research Association.

17 Guzdial, Mark. Does Contextualized Computing Education Help?, *ACM Inroads*, 1,4 (Dec. 2010), 4-6.

19 Guzdial, M. 2014. The most gender-balanced computing program in the USA: computational media at Georgia Tech, *Computer Education Blog*, September 2, 2014.

5 Barker, L. J. (2018) email communication, February 28, 2018.

# Our approach: Computing in the Arts

- ▶ Interweave opportunities for individualized and personally meaningful creative expression<sup>4</sup> through **each** of the **four years** of an undergraduate degree program.
- ▶ These **synthesis courses** encourage creative expression while applying required computing and artistic learning outcomes.
- ▶ Computing in the Arts (CITA) originated with a 2007 media computation course.
- ▶ Though the focus of this paper is on creative expression in the arts, we do not imply that creativity in computing happens only in the arts.

<sup>4</sup> Beghetto, R. A. & Kaufman, J. C. Toward a broader conception of creativity: A case for mini-c creativity. *Psychology of Aesthetics, Creativity, and the Arts*, 1, 2 (May 2007), 73–79.

# College of Charleston Profile

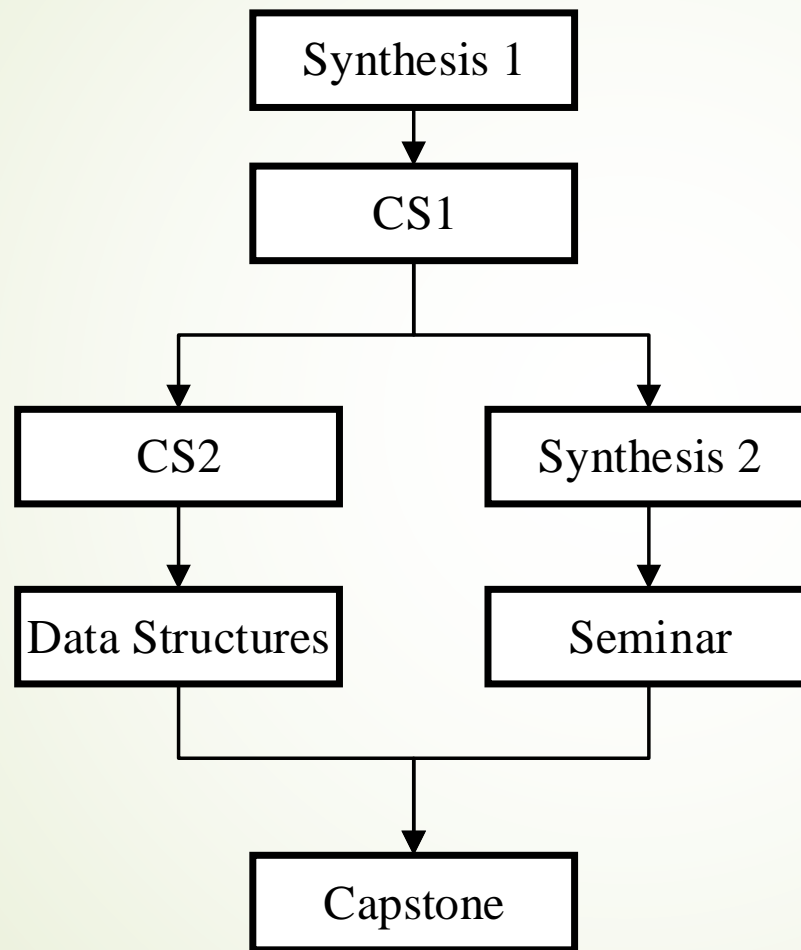
- ▶ State institution, primarily undergraduate student population
  - ▶ Percentage of in-state students: 68.6%
  - ▶ Admission rate: 84% (Fall 2016-17)
  - ▶ Middle fifty percent of incoming students in Fall 2018 ACT scores of 21-27 (in-state) and 24-29 (out-of-state).
- ▶ Focus on faculty teaching undergraduates, little to no use of TAs
- ▶ 10,375 undergraduate students
- ▶ 64.4% are women
- ▶ 19.1% are from underrepresented populations as of the first semester of the 2016 academic year

<https://today.cofc.edu/2018/08/15/class-of-2022-freshman-profile/>  
<http://cofc.edu/about/ataglance/>

# CITA Synthesis Courses

- ▶ Synthesis 1: basic programming concepts situated in an accessible and creative arts-themed context.
- ▶ Synthesis 2: apply software development concepts in the context of game programming.
- ▶ Synthesis 3 - Seminar: Students develop a proposal for a capstone project, which synthesizes creativity in the arts with computing (pre-req: three classes in chosen art area).
- ▶ Synthesis 4 - Capstone: In the fourth-year capstone practicum, students implement their projects according to their proposal plans.

# CITA Curriculum Prerequisite Flowchart



Additionally, CITA majors complete 9 credits in upper-division CSCI coursework, and 18 credits in their art concentration area

# Enrollments: CITA versus CSCI (2011-2017)

CITA Synthesis Courses				CSCI Courses			
Course	F	M	F%	Course	F	M	F%
Synth1	224	384	36.8%	CS1	350	860	28.9%
Synth2	50	107	31.9%	CS2	217	650	25.0%
Seminar	24	37	39.4%	Software Architecture	56	241	18.9%
Capstone	21	27	43.8%	Practicum	45	199	18.4%



# Synthesis 1: Common Learning Outcomes

- Apply numeric and string **data types** to represent information.
- Apply **variables** in program development.
- Understand **arithmetic operators** and apply them to design expressions.
- Understand **loops** and use them to design processes involving repetition.
- Understand and apply processes involving **selection**.
- Understand **functions** and use them to design processes involving modularization.
- Use predefined **classes** in program development.
- Learn basic principles for **group collaboration**.

# Synthesis 1: Computers, Music and Art

- ▶ Example Assignment: Create a sonification of an interesting image.
- ▶ Samples of student work:



See <https://vimeo.com/64109534>



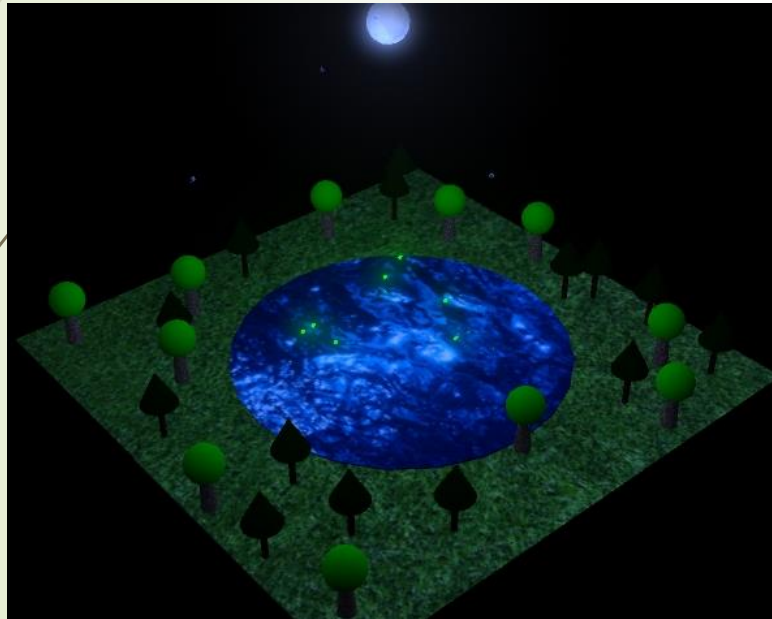
See <https://vimeo.com/64101616>

# Synthesis 1: Computers, Music and Art

- ▶ Example Assignment: Create a sonification of an interesting image
- ▶ Computing learning outcomes:
  - ▶ Apply a **2D list** data structure to store image data (RGB pixels).
  - ▶ Apply a **nested count-controlled loop** to iterate over the pixels.
  - ▶ Apply a **mapping** strategy to convert data from one domain (pixels) to another (notes).
- ▶ Artistic learning outcomes:
  - ▶ Compose an original piece by selecting a beautiful or compelling image and then designing a set of musical parameters to convert this image to sound. Musical parameters include **pitch** and **scale, dynamics, timbre, and instrumentation**.

# Synthesis 1: Animation & Virtual Worlds

- ▶ Example Assignment: Create a particle system animated 3D scene.
- ▶ Samples of student work (Python code inside Autodesk Maya)



Fireflies over a moonlit lake



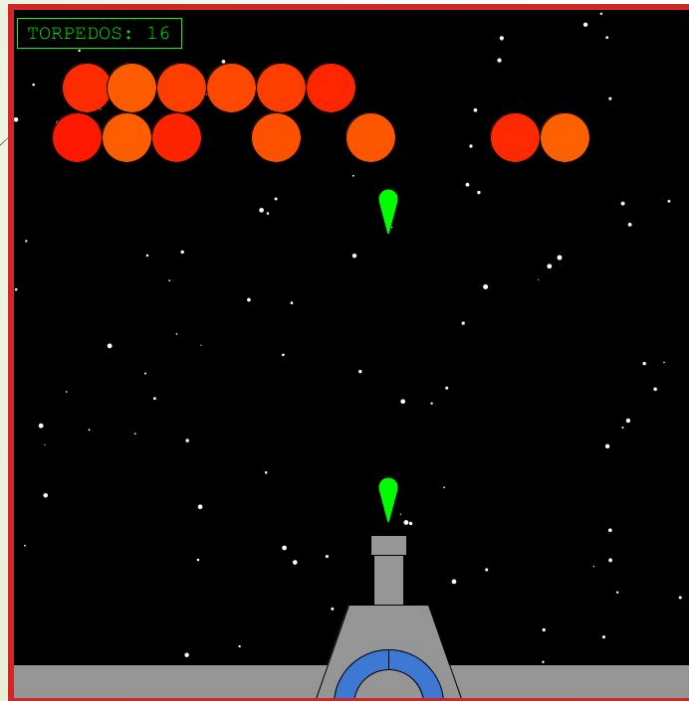
Helicopter chasing an Audi in the rain

# Synthesis 1: Animation & Virtual Worlds

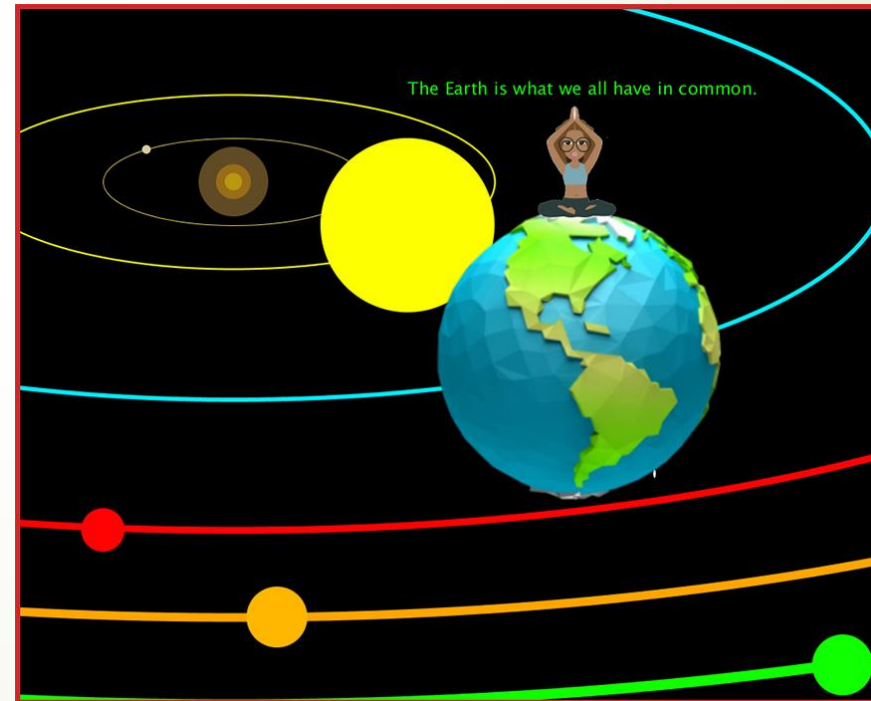
- ▶ Example Assignment: Create a particle system animated 3D scene
- ▶ Computing learning outcomes:
  - ▶ Apply a **list** data structure to represent particles each having at least a position (x,y,z) and velocity. You may add extra attributes for color, lifetime, size, etc.
  - ▶ Apply a count-controlled loop to **iterate** over the particles.
  - ▶ Apply a Boolean stopping condition to determine when a particle has expired and needs to be either re-generated or removed from the list.
  - ▶ Apply keyframe animated properties to visualize each particle
  - ▶ Apply basic **physics equations** to update particle position and velocity
- ▶ Artistic learning outcomes:
  - ▶ Compose an original 3D scene by arranging existing 3D models to create a backdrop that fits the visuals of your particle effect. For example, create fireworks over a cityscape.

# Synthesis 1: Digital Media Programming

- Example Assignment: Design an interactive art composition or a game.
- Samples of student work:



Space Snake



Mama Earth, Female Ruler of the Galaxy

# Synthesis 1: Digital Media Programming

Computing learning outcomes:

- ▶ Use **Object Oriented Programming** to include at least one class.
- ▶ Incorporate various **data types**, including arrays and text.
- ▶ Comment liberally to properly **document** the program.
- ▶ Apply variables, **conditionals**, and/or **loops** to create non-static objects.

Artistic learning outcomes:

- ▶ Most graphics must be **created from code**, although you may use a limited amount of raster images.
- ▶ Apply **principles of graphic design** to result in an aesthetically pleasing interface.

# Synthesis 2: Game Programming

## ► Design Learning Outcomes:

- Apply an iterative creative design process including **prototypes** (paper, digital, and code), gathering player **feedback**, and **revision**.
- Apply **game design principles** to model player experience goals, balance challenge versus engagement, design sprite artwork.
- Apply **user interface design principles** to provide feedback.

## ► Computing Learning Outcomes:

- Apply an **iterative** software design process (testing plan, design, development).
- Apply **lists** of objects to animate objects and check collisions.
- Apply **finite-state machines** to control behavior of game objects.
- Apply **maze navigation** algorithms in a 2D tile-based map.



# Synthesis 2: Game Programming

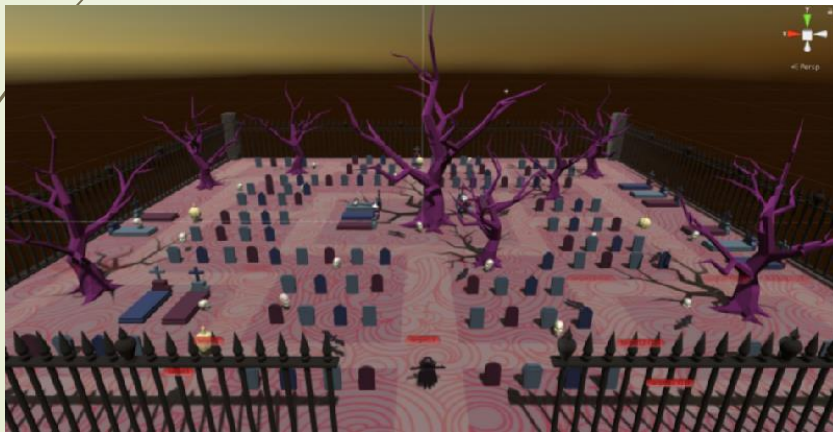
- ▶ The course culminates with a team game-development project exercising all course outcomes, which is presented and play-tested in the final class meeting.
- ▶ We chose to use Processing, since it bridges the Python and Java languages used in our CS1 and CS2 courses.



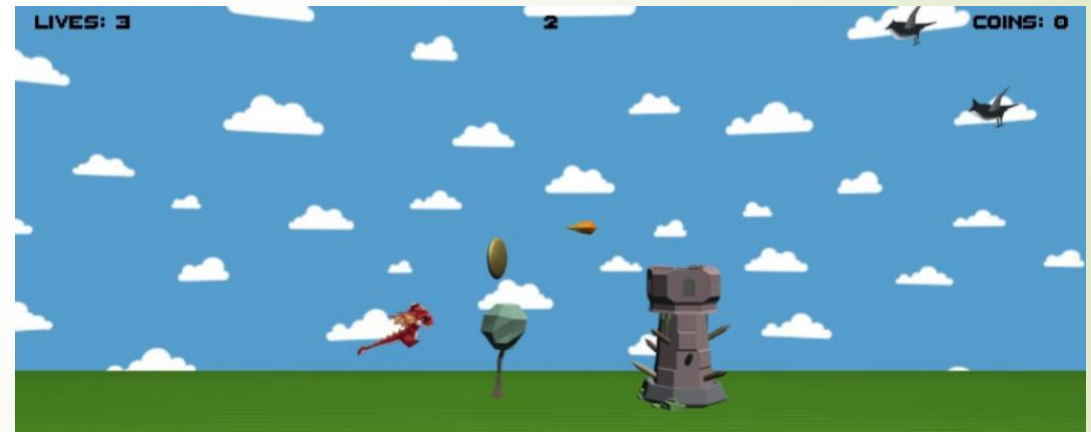
Sample game:  
2D tile grid  
Randomly placed  
objects  
Bird diving moves  
Cat jumps and  
lands on platforms

# Synthesis 2: Game Programming

- ▶ The most recent offering used Unity Game Engine and the C# language.
- ▶ Designed in response to student requests for a Game Programming II.
- ▶ The course content featured 3D graphics.



Vampire Run – collect skull tokens before sunrise



Dragon Joyride – fly to dodge endlessly scrolling obstacles and collect bonus items. Breathe fireballs to destroy flying obstacles.

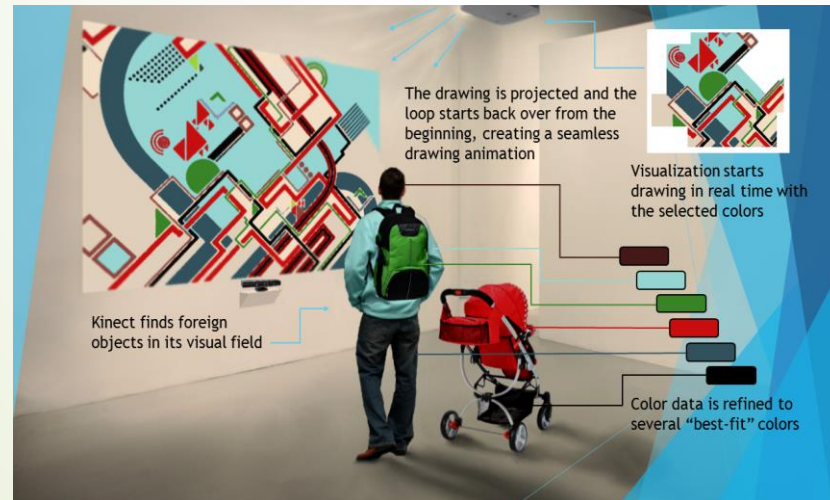
# Synthesis 3: Seminar

## Learning Outcomes:

- ▶ Explore archived examples of previous CITA capstone projects.
- ▶ Conduct literature searches to identify prior works that blend art and computing.
- ▶ Apply iterative software development through prototyping, revision, and testing.
- ▶ Produce a working **code prototype** which demonstrates a solution for a critical technical element of the proposed project.
- ▶ Write a formal project proposal which describes:
  - ▶ how you synthesize art & computing
  - ▶ expected outputs and behaviors
  - ▶ algorithm design and justification
  - ▶ task timeline

# Synthesis 3: Seminar

- ▶ Students must interact with faculty **mentors** in art and computing, who offer early feedback on artistic and computing aspects of the students' project ideas.
- ▶ These early contacts help students to (a) create projects that better synthesize art and computing, (b) identify and correct problems early on, and (c) help students to change directions when necessary.



## ***Proposal: Palette Jack***

Interface with MS Kinect in C++  
Compute color palette of image  
Dynamic 2D visuals animated  
using computed color palettes

# Synthesis 4: Capstone Practicum

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- Students implement their proposed projects with guidance from the instructor and art and computing mentors.
- Students periodically present work-in-progress updates to their peers.
- Projects are presented in front of invited art and computing faculty.



Snowboard simulation - Spring 2019  
(Unity, Arduino gyroscope)



I feel anticipation, happiness,  
and surprise

Machine learns  
emotional  
response to art -  
Spring 2019  
(Google Cloud  
Machine  
Learning, WikiArt  
Emotions dataset)

# Synthesis 4: Learning Outcomes

- Present work-in-progress demos of milestones to peers.
- Consult with one art **mentor** and one computing mentor to solicit feedback on progress.
- Offer **constructive feedback to third-year synthesis students** as they work through the process of identifying their projects.
- Make a formal presentation of the completed project.
- Write report summarizing technical details of the solution and reflecting upon the completed work.

# Observations and Lessons Learned

- ▶ Even if one cannot implement a whole curriculum, starting small – even at the level of a single course – has a positive impact.
- ▶ We observed that these courses attracted many non-majors and women, encouraging us to create the CITA degree.
- ▶ Our courses “Computers, Music, and Arts” and “Game Programming” were offered before our CITA degree was designed (Fall 2006).

# Observations and Lessons Learned

- ▶ It could also be argued that the consistently high percentage of female students through all four-years of the CITA synthesis courses supplies the necessary critical mass and role models which contribute to increased self-efficacy due to vicarious experience (Bandura, 1986; Bandura, 1997).
- ▶ Introducing opportunities for creative expression anywhere within a traditional Computer Science curriculum could help.
  - ▶ For example, the concept of lists of objects may be taught in a typical CS2 or Data Structures course by implementing insert, search, and delete operations for student records.
  - ▶ To offer greater opportunity for creative expression, lists of objects could be used to create an animated particle system effect.



# Conclusions

- ▶ A six-year longitudinal study demonstrates that combining creative expression and the arts with core computer science courses (including computer programming, data structures and software engineering) results in graduating 46% female students (compared to the 20% traditional nationwide statistic).
- ▶ In our experience, 72% of CITA graduates are placed in CITA-related jobs or graduate studies that involve computing or arts, with a majority of them in jobs that require their computing skills.
- ▶ A CITA-like degree is a viable *complement* to a traditional Computer Science degree, as it prepares students for careers in computing, while at the same time eliminating the gender disparity found in traditional computing degrees.

# Thank you

- ▶ Feel free to contact any of the authors if you have questions.
- ▶ We are happy to share materials if you wish to adopt these ideas.
  - ▶ <http://blogs.cofc.edu/bareswh/sigcse-2019/>
  - ▶ <http://blogs.cofc.edu/manaris/teach/>
- ▶ William H. Bares, Bill Manaris, Renée McCauley, Christine Moore
  - ▶ [ bareswh, manarib, mccauleyr, moorec ] @cofc.edu

# Supplemental Slides (for Questions)

- ▶ Data collection methodology & limitations
- ▶ CITA attracts new/different students to computing
- ▶ Placements of CITA graduates
- ▶ Other institutional profiles:
  - ▶ Georgia Tech
  - ▶ University of Colorado
  - ▶ Harvey Mudd College

# Data Collection Methodology

- ▶ Office of Institutional Research at our institution provided:
- ▶ final grade records from Fall 2011 to Spring 2017
- ▶ Data included course name, course number, section, final student grade, student gender, student race, and student major (or majors, if more than one).
- ▶ Our institution's student records system stores only the latest (current, or final) student major as of Spring 2017.
  - ▶ Unable to track when students changed majors.
- ▶ We wrote various Python scripts to clean up and compute the statistics reported.

# Synthesis 1 Courses Attract New Students to Computing

## Top Seven Non-Computing Majors by percentage enrolled in Synthesis 1

- **Business (22%, or 53 of 239)**
- **Arts (22%, or 52 of 239)**
- Lab Sciences-Math (16%, or 39 of 239)
- Social Sciences (10%, or 23 of 239)
- Humanities (4%, or 11 of 239)
- Education (3%, or 9 of 239)
- Languages (1%, or 3 of 239)

## Top Seven Non-Computing Majors by percentage enrolled in Computer Science 1

- **Lab Sciences-Math (49%, or 202 of 450)**
- Business (17%, or 75 of 450)
- Social Sciences (6%, or 25 of 450)
- Arts (5%, or 22 of 450)
- Humanities (3%, or 14 of 450)
- Languages (2%, or 8 of 450)
- Education (1% or 4 of 450)

# Placements of CITA Graduates

- ▶ 72% of CITA graduates are placed in CITA-related jobs or graduate studies that involve computing or arts, with a majority of them in jobs that require their computing skills
- ▶ digital collections coordinator at College of Charleston Halsey Center for the Arts
- ▶ performing musician and works for non-profits who advocate for social justice
- ▶ user interface design and testing
- ▶ support specialist
- ▶ website designer and programmer
- ▶ graduate school (5 to Clemson Digital Production Arts, MFA)

# Georgia Tech Profile

- ▶ State institution, doctoral granting
- ▶ Entering class of Fall 2018:
  - ▶ Percentage of in-state students: 68%
  - ▶ Admission rate for in-state applicants: 37%
  - ▶ Admission rate for out-of-state applicants: 19%
  - ▶ ACT composite scores range 31-34.
- ▶ 15,573 undergraduate students
- ▶ 38% are women

<https://admission.gatech.edu/first-year>

<https://www.usnews.com/best-colleges/georgia-institute-of-technology-1569>

# University of Colorado Profile

- ▶ State institution, doctoral granting
- ▶ Entering class of Fall 2018:
  - ▶ Percentage of in-state students: 50.8%
  - ▶ Admission rate: 76.6%
  - ▶ ACT composite score 27.6
- ▶ 29,091 undergraduate students
- ▶ 44% are women

[https://www.colorado.edu/oda/sites/default/files/attached-files/freshmanprofilefall2018\\_0.pdf](https://www.colorado.edu/oda/sites/default/files/attached-files/freshmanprofilefall2018_0.pdf)  
<https://www.usnews.com/best-colleges/university-of-colorado-boulder-1370>



# Harvey Mudd College Profile

- ▶ Private, undergraduate institution
- ▶ Entering class of Fall 2018:
  - ▶ Percentage of in-state students: 42%
  - ▶ Admission rate: 14.5%
  - ▶ Middle fifty percent ACT composite scores of 34-35
- ▶ 844 undergraduate students
- ▶ 52% are women

<https://www.hmc.edu/admission/discover/>