
# iSchedule to Personalize Learning

## A Novel Approach to Timetabling in Practice

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# Agenda

**Operational problem**

**Solution approach**

**Challenges**

- Constructing the graph
- Handling graphs that cannot be colored in *k* colors
- Scheduling electives
- Adhering to course capacities

**Implementing our solution in practice**

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# Background

## Bringing personalized education to NYC school children

**The NYC Department of Education is experimenting with education models that emphasize personalized learning**

**The NYC innovation zone (iZone) schools offer ability-based tracks in multiple subject areas and give students control over their educational planning.**

# The difficulties of personalized education

## A new scheduling problem

**In order to customize student learning experiences, the iZone schools would like to build a master schedule that:**

1. Allows students to meet their requirements
2. Enables students to take their preferred electives
3. Adheres to resource constraints

# The difficulties of personalized education

## A new scheduling problem

**Existing scheduling software used by NYC does not generate master schedules, but rather, assigns students to a pre-determined master schedule.**

**Scheduling in practice has challenges not faced in academic research**

- Human element—hard to measure quality of schedule
- Cannot relax constraints of our choosing
- Time constraints for developing model and solution

# The difficulties of personalized education

## Novel challenges of this scheduling problem

**Individualized instruction results in a large number of constraints about which courses cannot take place at the same time**

- E.g., if a student is required to take Algebra and Biology, these two courses must be scheduled for different times
- Students in the same grade do not always take the same set of courses, so a large number of *conflict sets* arises

# The difficulties of personalized education

## Unique constraints to satisfy

| Teachers | Courses | Rooms |
|---|---|---|
| Availability | | |
| Union laws | Capacity | |
| Max load | # meetings | Flexibility |
| Common planning | Single/double pds | |
| Co-taught/team-taught | | |

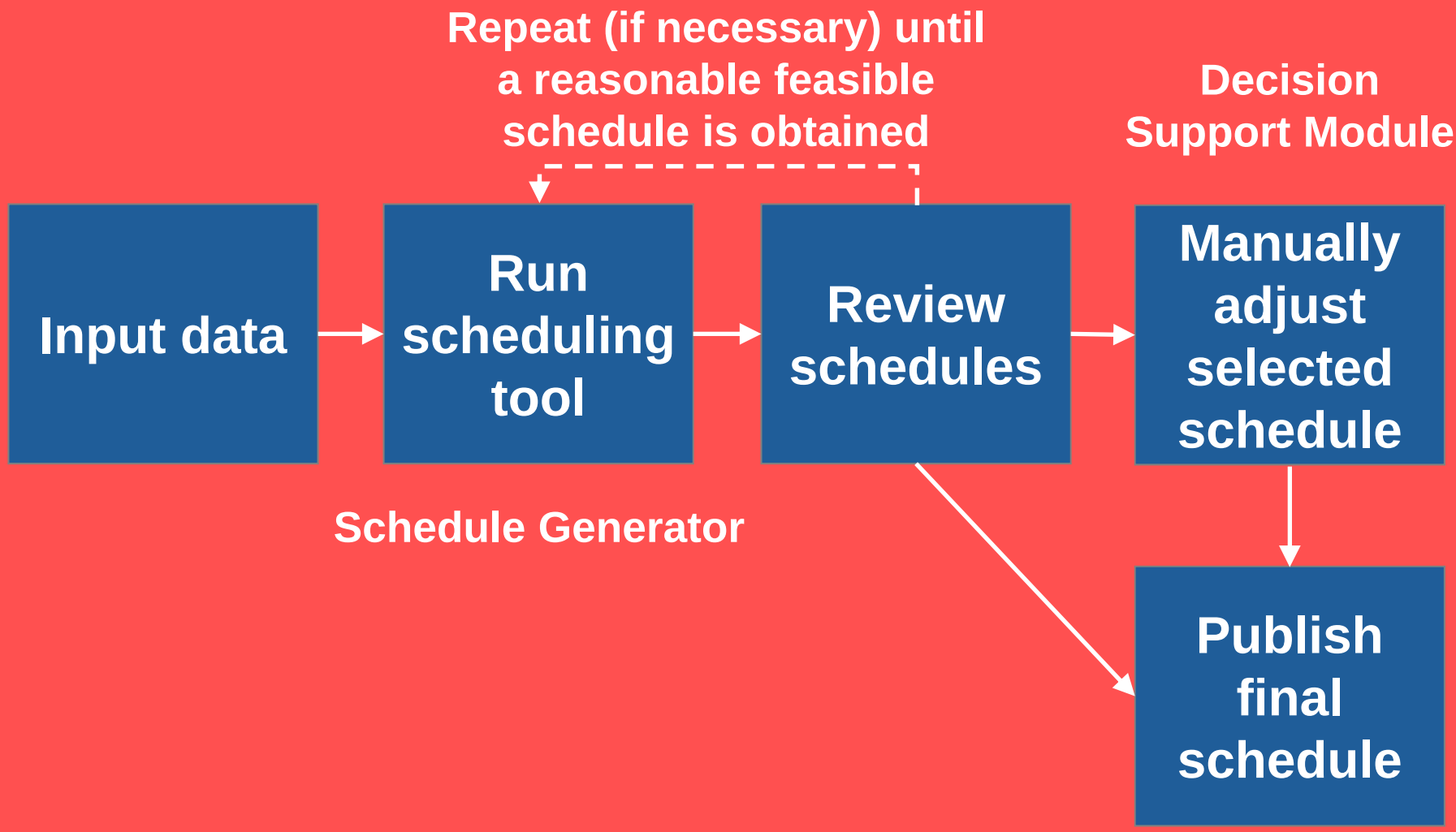
**Ribbon Schedule**

| | A | B |
|---|---|---|
| 1 | Algebra | Algebra |
| 2 | Phys Ed | Music |
| 3 | Lunch | Lunch |
| 4 | Biology | Biology |

**Non-ribbon Schedule**

| | A | B |
|---|---|---|
| 1 | Algebra | Biology |
| 2 | Phys Ed | Biology |
| 3 | Lunch | Algebra |
| 4 | Biology | Lunch |

# Developing a tool to automate scheduling



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# Choosing an approach

**This problem has not previously been explored**

- Existing problems are course scheduling, school timetabling, and student scheduling
- This problem contains the complexities of all three

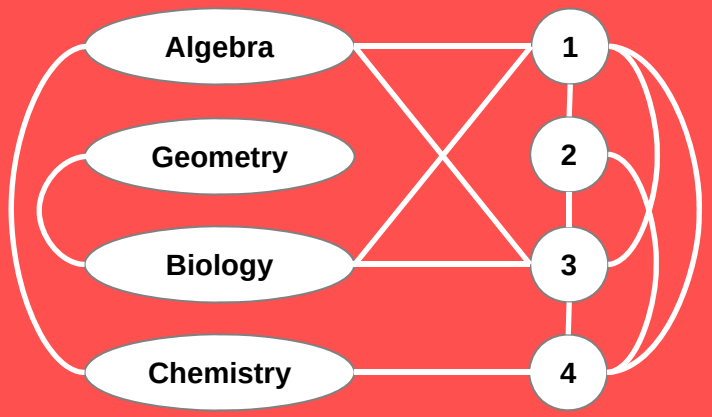
**Some approaches to existing scheduling problems**

- Direct heuristics
- Graph coloring, bipartite matching, network flow
- Integer programming
- Evolutionary algorithms and simulated annealing

# Model

**Problem is modeled as a graph**

- One node for each course meeting
- One node for each period
- Edges represent the relationship “cannot take place at the same time”




***The problem reduces to graph coloring***

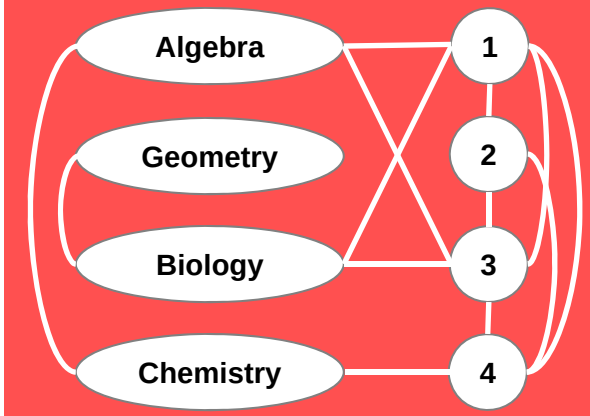
# Generating schedules

## 1. List of constraints

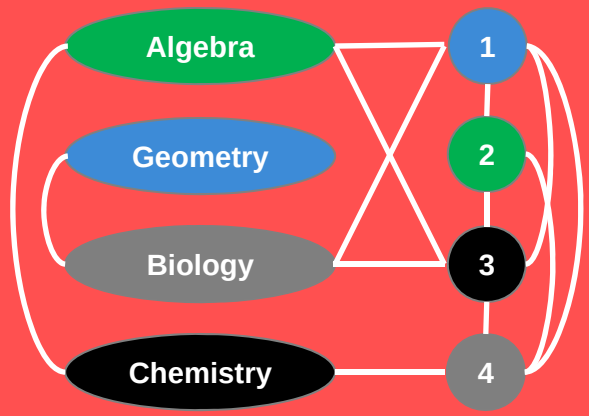
| Student | Course |
|---|---|
| Adeline | Algebra |
| Adeline | Chemistry |
| Anjuli | Geometry |
| Anjuli | Biology |

| | | Period Available | | | |
|---|---|---|---|---|---|
| Course | Teacher | 1 | 2 | 3 | 4 |
| Algebra | Euclid | | ✓ | | ✓ |
| Geometry | Des Cartes | ✓ | ✓ | ✓ | ✓ |
| Biology | Darwin | | ✓ | | ✓ |
| Chemistry | Curie | ✓ | ✓ | ✓ | |

## 2. Graph representation




## 3. Colored graph




## 4. Publish schedule

| Pd | Course |
|---|---|
| 1 | Geometry |
| 2 | Algebra |
| 3 | Chemistry |
| 4 | Biology |

| Pd | Course |
|---|---|
| 1 | |
| 2 | Algebra |
| 3 | Chemistry |
| 4 | |

| Pd | Course |
|---|---|
| 1 | Geometry |
| 2 | |
| 3 | |
| 4 | Biology |

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# Constructing the graph

**In some cases, a student has choices about how to satisfy a course requirement.**

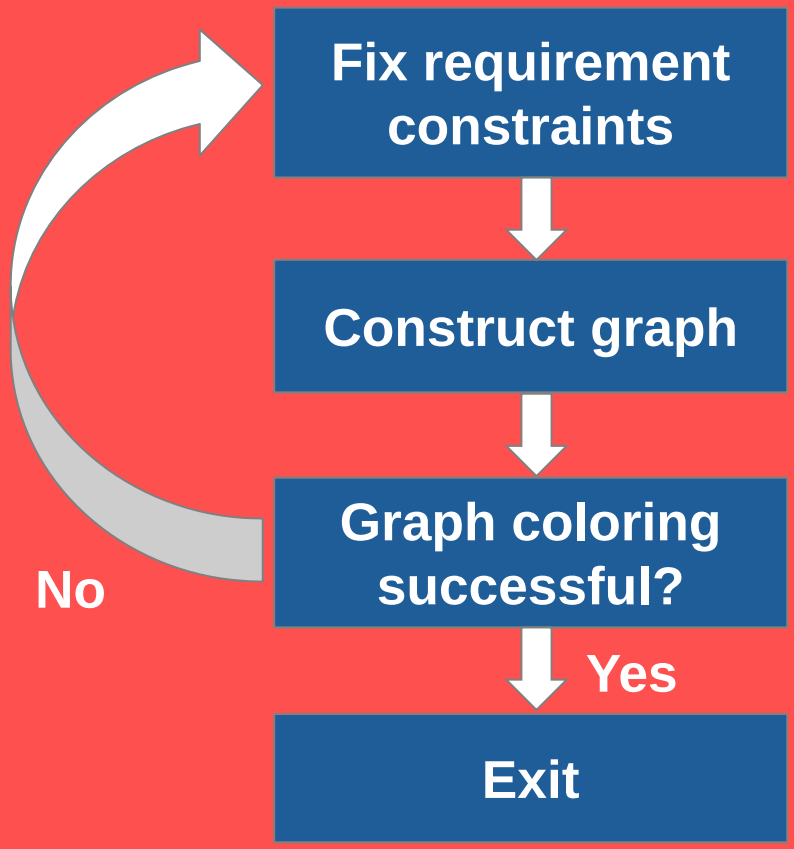
- Example: a student may be required to take Algebra and *either* Biology *or* Chemistry

**This gives us choices about how to construct our graph**

- In the above example, *either* Algebra and Biology cannot take place at the same time *or* Algebra and Chemistry cannot take place at the same time

# Constructing the graph

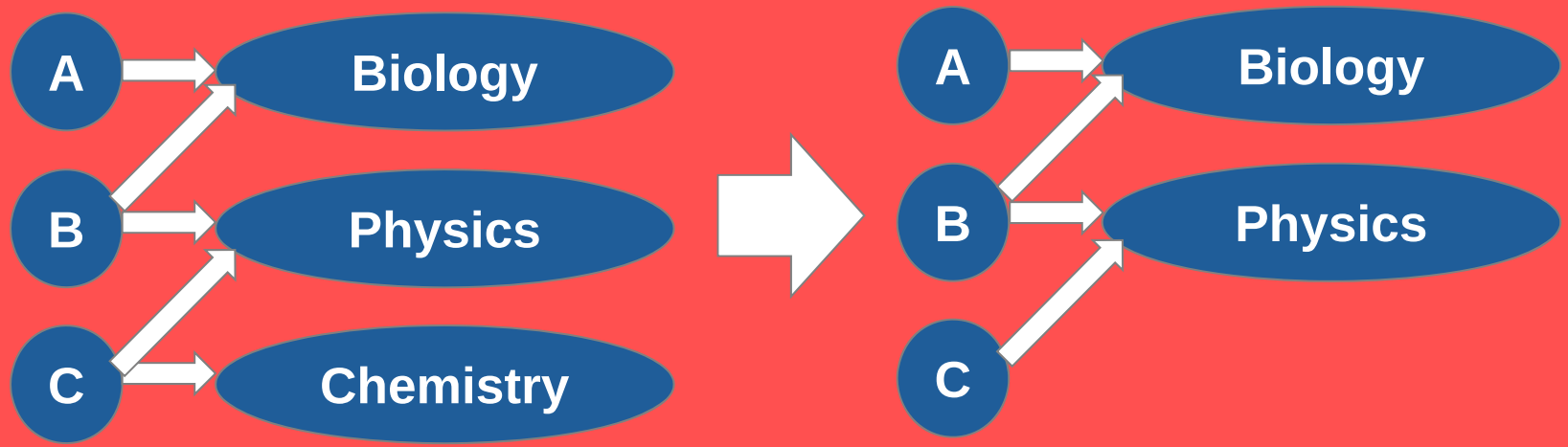
**To avoid exploring all combinations of student requirements:**



# Constructing the graph

## Generating a minimum conflict set

**To increase the likelihood that the graph is colorable, we construct what we call a *minimum conflict set,* a set of constraints that is designed to be as small as possible while still accounting for all student requirements.**

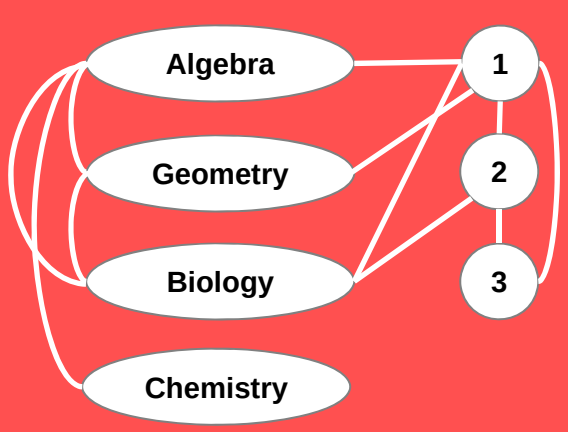


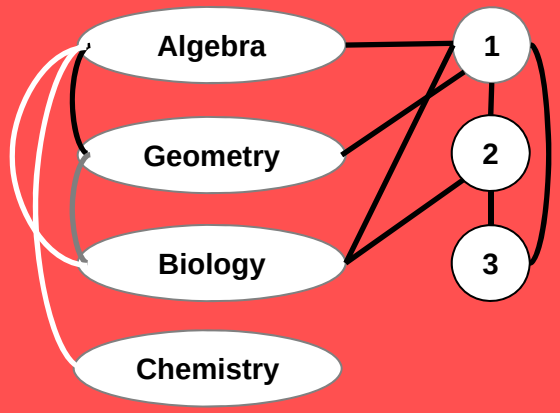
# Handling graphs that cannot be colored in *k* colors

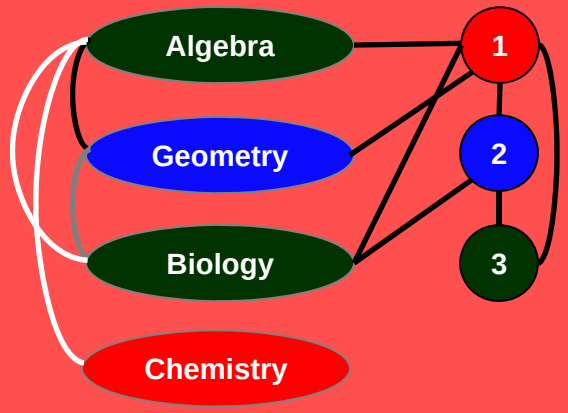
| Student | Course |
|---|---|
| Adeline | Algebra |
| Adeline | Chemistry |
| Anjuli | Geometry |
| Anjuli | Biology |

| Student | Course |
|---|---|
| Gerald | Geometry |
| Gerald | Biology |
| Mitchell | Algebra |
| Mitchell | Biology |

| | | Period Available | | |
|---|---|---|---|---|
| Course | Teacher | 1 | 2 | 3 |
| Algebra | Euclid | | ✓ | ✓ |
| Geometry | Euclid | | ✓ | ✓ |
| Biology | Darwin | | | ✓ |
| Chemistry | Curie | ✓ | ✓ | ✓ |

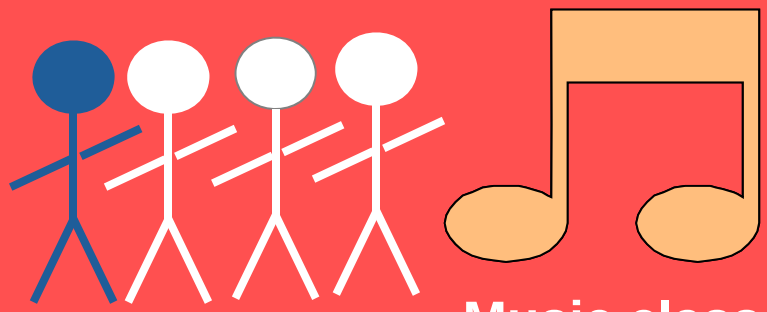


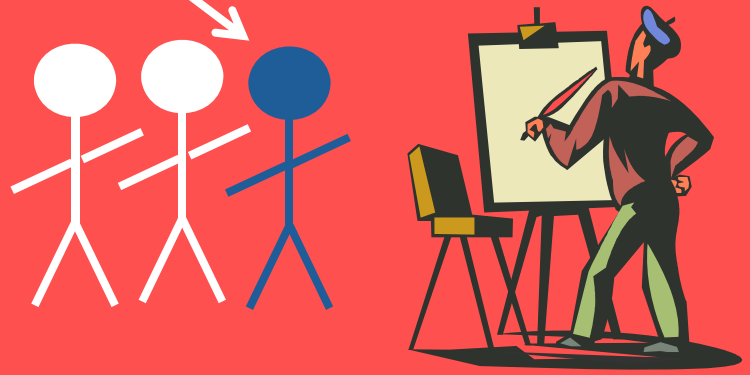




***Nodes are colored to minimize impact to students***

# Scheduling electives



Music class



Art class

**Scheduling electives is a tradeoff between number of electives scheduled and equity across students**

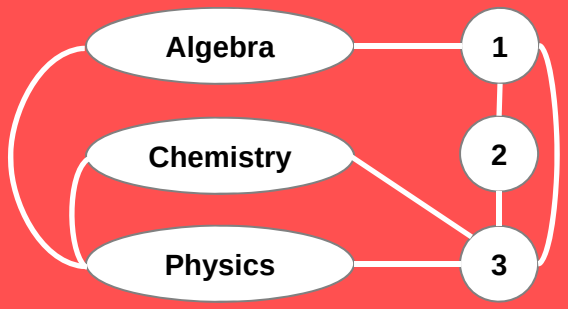
- Electives scheduled in order of popularity to maximize number of students who get an elective
- Priority given to students who did not get their first choice in order to achieve equity

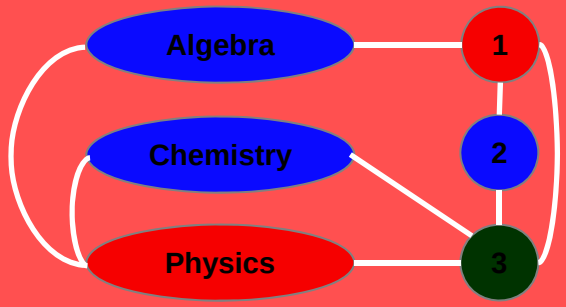
# Adhering to course capacities

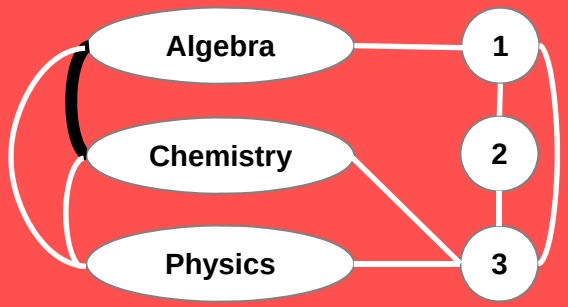
| Student | Course |
|---|---|
| Adeline | Algebra |
| Adeline | Chemistry |
| Adeline | Physics |

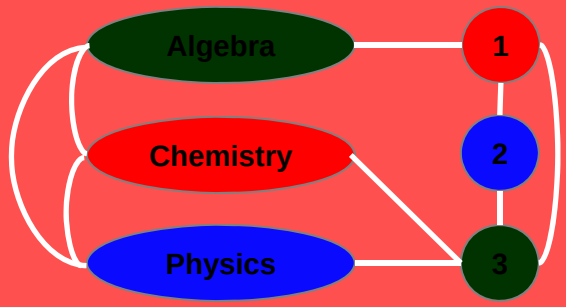
| Student | Course |
|---|---|
| Gerald | Algebra |
| Gerald | Chemistry |
| Gerald | Physics |

| Course | Teacher | Period Available 1 | 2 | 3 | Capacity |
|---|---|---|---|---|---|
| Algebra | Euclid | | ✓ | ✓ | 2 |
| Chemistry | Curie | ✓ | ✓ | | 1 |
| Physics | Curie | ✓ | ✓ | | 1 |



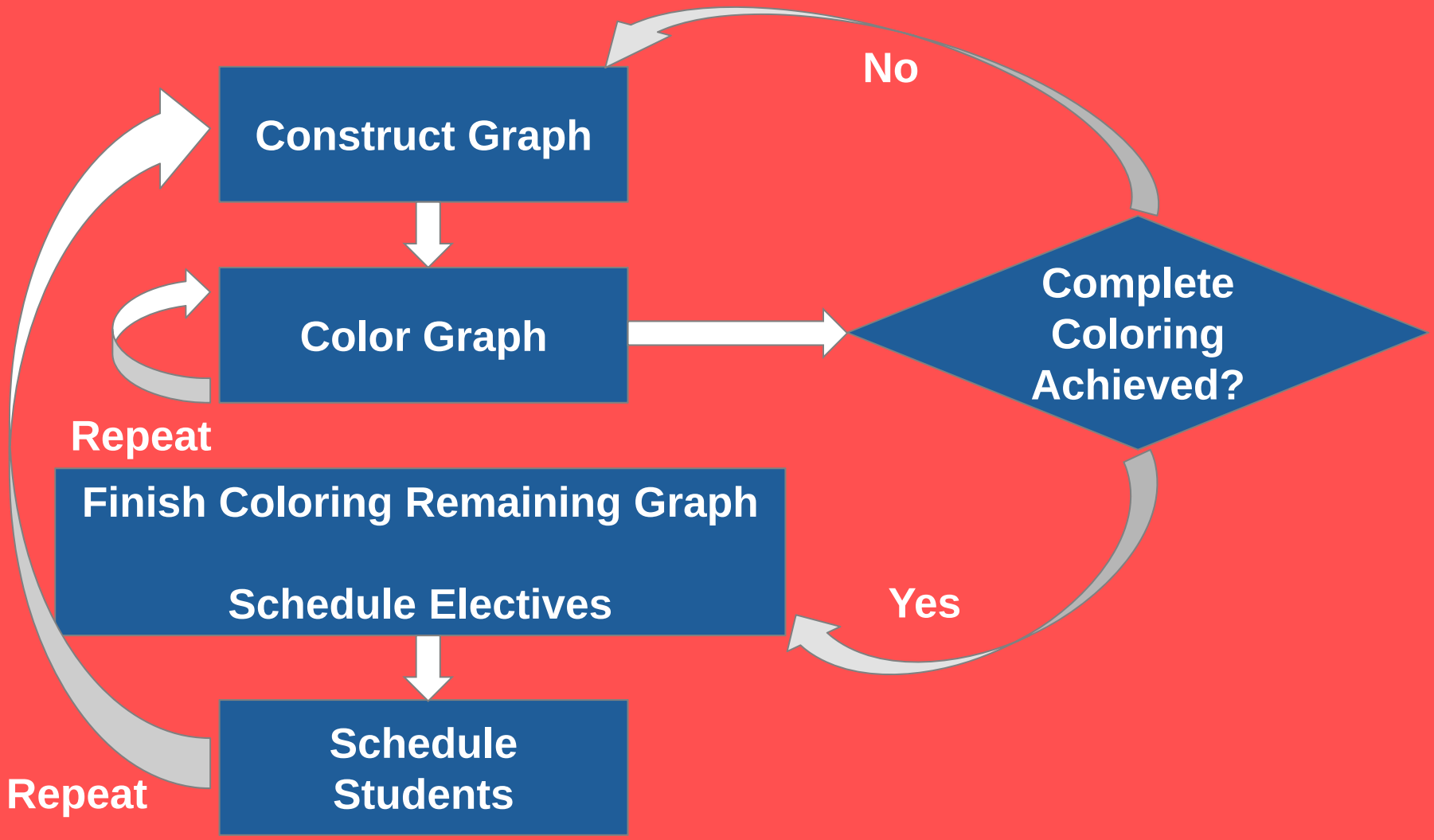




***Capacities must be taken into account in the graph construction step***

# Overall algorithm



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# Implementation: user interface


## Sample Inputs

### Teacher Course Load

| COURSE | SEC # | # 2-PD BLKS | # 1-PD BLKS | SIZE | SUBJ | REQ'D ROOM | TEACHER #1 | TEACHER #2 |
|---|---|---|---|---|---|---|---|---|
| GEOMETRY | 1 | 1 | 0 | 25 | MATH | 101 | EUCLID | |
| GEOMETRY | 2 | 1 | 0 | 25 | MATH | 101 | EUCLID | |
| GEOMETRY | 3 | 1 | 0 | 25 | MATH | 101 | DESCARTES | |
| GEOMETRY ADV | 1 | 1 | 0 | 25 | MATH | 101 | EUCLID | DESCARTES |

### Student Requirements

| LAST NAME | FIRST NAME | COURSE | REQUIRED | PREFERENCE |
|---|---|---|---|---|
| SMITH | JOHN | GEOMETRY | Y | |
| SMITH | JOHN | BIOLOGY | Y | 2 |
| SMITH | JOHN | CHEMISTRY | Y | 1 |
| SMITH | JOHN | ENGLISH | Y | |
| SMITH | JOHN | US HISTORY | Y | |
| SMITH | JOHN | FRENCH | Y | 1 |
| SMITH | JOHN | SPANISH | Y | 2 |
| SMITH | JOHN | ART | N | 3 |
| SMITH | JOHN | MUSIC | N | 2 |
| SMITH | JOHN | TENNIS | N | 1 |
| SMITH | JOHN | SWIM | | 4 |

# Implementation: user interface

## Sample Outputs

### Teacher Schedule

MR. EUCLID

| | A | B |
|---|---|---|
| 1 | GEOMETRY/SEC 1/RM 101 | GEOMETRY/SEC 1/RM 101 |
| 2 | GEOMETRY/SEC 2/RM 101 | GEOMETRY/SEC 2/RM 101 |
| 3 | | |
| 4 | | ADVISORY EUCLID/SEC 1/RM <NONE> |
| 5 | GEOMETRY/SEC 3/RM 101 | GEOMETRY/SEC 3/RM 101 |
| 6 | PLANNING EUCLID DESCARTES/SEC 1/RM <NONE> | |
| 7 | | PLANNING MATH DEPT/SEC 1/RM <NONE> |
| 8 | GEOMETRY ADV/SEC 1/RM 101 | GEOMETRY ADV/SEC 1/RM 101 |

### Student Schedule

JOHN SMITH

| | A | B |
|---|---|---|
| 1 | CHEMISTRY/SEC 1/RM 303 | CHEMISTRY/SEC 1/RM 303 |
| 2 | SPANISH/SEC 1/RM 102 | SPANISH/SEC 1/RM 102 |
| 3 | ART/SEC 1/RM ART | STUDY HALL/SEC 1/RM 201 |
| 4 | LUNCH/SEC 1/CAFETERIA | ADVISORY NEWTON/SEC 1/RM <NONE> |
| 5 | GEOMETRY/SEC 3/RM 101 | GEOMETRY/SEC 3/RM 101 |
| 6 | ENGLISH/SEC 2/RM 404 | ENGLISH/SEC 2/RM 404 |
| 7 | TENNIS/SEC 1/RM TENNIS | TENNIS/SEC 1/RM TENNIS |
| 8 | US HISTORY/SEC 1/RM 505 | US HISTORY/SEC 1/RM 505 |

# Using our solution in schools

## The iSchedule tool has been introduced to 3 schools

**"Current NYC Department of Education technology would not meet my scheduling needs, as we have a number of innovative programs that exceed the current technology. The iSchedule allows me to consider *all of the constraints* that are presented by a variety of student and teacher needs, *rather than using a one-size-fits-all model*.**

**Through this tool, I can generate many schedules that represent different priorities, and then choose amongst them. Allowing me to weigh the pros and cons of each schedule ensures that we are making the most informed decisions to best meet students' needs. By meeting our students' physical, academic, social and emotional needs, we are able to push them closer to the rigor necessary in college and the workforce."**

**-Jaime Dubei**
**Principal at Queens Collegiate**

# Future work

**Improvements to algorithm**

- Incorporate evolutionary or machine learning algorithm into graph construction or graph coloring
- Diagnose scheduling bottlenecks

**Improvements to user interface**

- Refine based on principals' feedback

**NYC wants to get more schools on board every year**

# Conclusions

- Individualized instruction poses a novel and challenging scheduling problem
- iSchedule presents one possible solution based on randomization, graph theory, and direct heuristics
- Implementation at iZone schools is successful
- Incorporating machine learning and/or evolutionary algorithms can improve the quality of schedules and speed of generation

# Q&A