A Linear Programming Model for Scheduling Medical School Clinical Experience

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“The Low Hanging Fruit”

• Some scheduling issues are mathematically simple
• Good relationships with collaborators, knowledge of the problem are essential
• Solved by a team of undergraduates in a few weeks during the school year
• Tangible impact, shorter timeframes
Changes in Medical Education – “The Old Model”

Longitudinal Professional Development

Basic Science (M1)  Clinical Science (M2)

Abundance of science but little-to-no clinical exposure/patient contact

Clinical Rotations (M3)  Clinical Rotations and Electives (M4)

Abundance of clinical exposure but little-to-no continued science education

Adapted from: http://curriculum.med.umich.edu/faqs
Changes in Medical Education – The “New” Model

Scientific Trunk (M1)

Organ-Based Learning

Clinical Trunk (M2)

Clinical Rotations

Branches (M3 & M4)

Clinical Rotations and Electives

INITIAL CLINICAL EXPERIENCE (ICE)

Clinical Science

BRANCH-SPECIFIC SCIENCE (M4 PILOT)

Adapted from: https://medicine.umich.edu/medschool/education/md-program/curriculum/diagrams
Scheduling Challenges

• Assigning M1’s to clinics (ICE)
• Ensuring M4’s continue their science education while having the freedom to choose elective rotations (M4 Pilot)
The ICE Program

• Assigns 168 MI’s to clinics in which they shadow healthcare professionals subject to certain rules:

1. Every student must be assigned to exactly one clinic

2. Every clinic must have at least one student assigned to it

3. Every clinic has a maximum number of students it can take
The ICE Program cont.

- Assigns 168 MI’s to clinics in which they shadow healthcare professionals subject to certain rules:
  4. If a student was assigned to an inpatient clinic previously, he or she must be assigned to an outpatient clinic (and vice versa)
  5. Only students with cars can be assigned to off-site clinics
  6. Students enrolled in Medical Spanish must be assigned to on-site clinics
  7. Each student lists their two least desired clinics
ICE Model Formulation - Constraints

1.) Student Coverage Requirements
   Every student $s$ must be assigned to exactly one open clinic

   \[ \sum_{c \in C} x_{sc} = l_c, \quad \forall s \in S \]

2.) Clinic Capacity Requirements
   The number of students assigned to clinic $c$ must be at least 1 if open and not exceed clinic capacity $u_c$

   \[ l_c \leq \sum_{s \in S} x_{sc} \leq u_c, \quad \forall c \in C \]
ICE Model Formulation - Constraints

3.) Inpatient-Outpatient Clinical Experience Requirements
   Every student $s$ should fulfill one inpatient clinical experience and one outpatient clinical experience

$$
\sum_{c \in C_O} a_s x_{sc} + \sum_{c \in C_I} b_s x_{sc} = 1 - u^i_s - u^o_s, \quad \forall s \in S
$$

4.) Student Car Requirements
   Only students with cars should be assigned to offsite clinics

$$
\sum_{c \in C_R} x_{sc} = z_s + u^c_s, \quad \forall s \in S
$$

5.) Medical Spanish Requirements
   Students registered for Medical Spanish should be assigned to onsite clinics

$$
\sum_{c \in C_P} x_{sc} = 1 - u^m_s, \quad \forall s \in S_M
$$
Objective Function:

\[
\begin{align*}
\text{min} & \quad \sum_{s \in S} \sum_{c \in C} \nu_{sc} x_{sc} \\
& \quad + c_1 \sum_{s \in S} [\nu_s^i + \nu_s^o] \\
& \quad + c_2 \sum_{s \in S} \nu_s^c \\
& \quad + c_3 \sum_{s \in S_M} \nu_s^m
\end{align*}
\]

- Assignments to least-preferred clinics
- Inpatient-Outpatient violations
- Car Violations
- Medical Spanish Violations
Revised Model Implementation

- Implemented in Open Solver
- Run time < 15 seconds
- Outputs number of violations of each type
- Worked with program directors to fine-tune assignments
- Adjusted weights in accordance with their desires
- Two semesters scheduled so far
- Plans to add functionality going forward
The M4 Pilot Program

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Systems</th>
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<td>Diabetes</td>
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<td>Trauma (Biomechanics/Mechanism of injury)</td>
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<tr>
<td>(Pathophysiology/Treatment)</td>
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<td>Diabetes</td>
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<tr>
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<td>(Pathophysiology/Diagnosis/Imaging)</td>
</tr>
</tbody>
</table>
• Assigns M4’s to student groups working on a specific science activity in a specific month subject to:

1. Each student must complete three out of four science activities associated with their branch

2. Students can only complete science activities based on cases that were seen during that particular rotation

3. Each group may have 3-5 students from any branch, but groups of 4 are strongly preferred
The M4 Pilot Program cont.

• Assigns M4’s to student groups working on a specific science activity in a specific month subject to:

4. Students specify their least desired science activity for their branch

5. Students can only participate in science activities within their branch requirements

6. Students can only participate in one science activity per month

7. Students cannot participate in the same science activity twice
1.) Group Size Requirements
Each student group must contain at least 3 and at most 5 students

\[3y_{am} \leq \sum_{s \in S} x_{sam} \leq 5y_{am}, \quad \forall a \in A, m \in M\]

2.) Group Size Preference
Each student group should contain four students plus or minus any groups of five or groups of three, respectively

\[\sum_{s \in S} x_{sam} = 4y_{am} + (n_{am}^+ - n_{am}^-), \quad \forall a \in A, m \in M\]

3.) Science Activity Completion Requirements
Each student must complete exactly three of four approved science activities within their branch requirements

\[\sum_{a \in A} \sum_{m \in M} a_{sa} x_{sam} = 3, \quad \forall s \in S\]
4.) Preventing Unapproved Assignments
Students cannot be assigned to science activities not within their branch requirements

\[ \sum_{a \in A} \sum_{m \in M} (1 - a_{sa})x_{sam} = 0, \quad \forall s \in S \]

5.) Activity Eligibility Requirements
Students can only complete a science activity in month \( m \) that is seen in the clinical rotation they select for that month.

\[ x_{sam} \leq e_{sam}, \quad \forall s \in S, a \in A, m \in M \]

6.) Prevention of Duplicate Assignments
Students cannot be assigned to a particular science activity more than once

\[ \sum_{m \in M} a_{sa}x_{sam} \leq 1, \quad \forall s \in S, a \in A \]

7.) Maximum Number of Science Activities per Period
Students cannot be assigned to more than one science activity per month

\[ \sum_{a \in A} x_{sam} \leq 1, \quad \forall s \in S, m \in M \]
M4 Pilot Program Model - Objective

Objective Function:

\[
\min \quad c_1 \sum_{s \in S} \sum_{a \in A} \sum_{m \in M} u_{sa} x_{sam} + c_2 \sum_{a \in A} \sum_{m \in M} n_{am}^+ + c_3 \sum_{a \in A} \sum_{m \in M} n_{am}^-
\]

- Assignments to undesired activities
- Number of groups containing 5 students
- Number of groups containing 3 students
Conclusion and Future Work

• Large impact from simple, straight-forward problems
• Program administrator workload reduction
• Higher medical student satisfaction
• Undergraduate-led project teams
• Long-term collaboration with the medical school
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University of Michigan Medical School
Questions / Comments
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