The strategic structure of medical education:

How game theory reveals the gap between collaborative values and competitive incentives



HELEN H. GLASER STUDENT ESSAY AWARD WINNER



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Introduction

Every February, thousands of medical students participate in one of the most sophisticated applications of game theory in modern society: the National Resident Matching Program (NRMP). The algorithm, based on work that earned Alvin Roth the 2012 Nobel Prize in Economics, elegantly solves a complex coordination problem. Students rank residency programs honestly; programs rank students, and a computerized mechanism produces stable matches that neither party can improve through strategic misrepresentation. By aligning truthful ranking with applicants' interests, the Match offers a rare example of deliberate mechanism design in medical education.[1,2]

The rest of medical education is built on misaligned incentives, competitive structures that punish cooperation, and institutional rhetoric that preaches teamwork while rewarding cutthroat individualism. Medical schools teach that compassion and collective welfare define good physicians. Then they place students in systems where helping a peer could mean losing a residency spot. This contradiction emerged through years of policymaking, as committees addressed immediate concerns without fully considering how each change would alter incentives across medical education. Individual culture and character matter, but they cannot fully explain a problem built into the system itself.

Game theory identifies the structural incentives behind behaviors that are often attributed to individual shortcomings. Students skip lectures to prepare for board exams, as those scores carry greater weight, which is a calculation easily mistaken for laziness. Schools issue uniformly positive recommendation letters to avoid disadvantaging their graduates, even though the practice eventually strips those letters of meaning and may appear dishonest. Residency programs expand their interview pools to preserve their options while competitors continue interviewing broadly. Each choice is rational in context, even when the combined result is costly and inefficient.

Theoretical framework

A few core concepts from game theory illuminate how medical education went wrong. The prisoner's dilemma describes scenarios where individual rationality produces collective disaster. Two suspects held separately can either cooperate (remain silent) or defect (betray each other). Mutual cooperation yields the best outcome for both, but defection is individually rational regardless of what the other chooses, so both defect, and both lose. Medical education is riddled with prisoner's dilemmas, situations where students, schools, and programs would all benefit from cooperation but face relentless pressure to defect.[3]

Nash equilibrium describes stable states where no player can unilaterally improve their outcome by changing strategy.[4] Stability only describes whether an outcome will persist; it says nothing about whether that outcome is desirable. Nash equilibrium can be disastrous for everyone involved, but it persists because unilateral deviation only makes things worse for the deviator. Much of medical education has settled into these stable catastrophes: behavioral patterns that serve no one well but that no individual actor can escape alone. Mechanism design asks the reverse question: instead of taking a game as given and solving for optimal strategy, how do you build a game that produces the outcomes you actually want?[5] The NRMP demonstrates what deliberate mechanism design can accomplish. Much of the rest of medical education developed incrementally, without sustained attention to the strategic behavior its policies would encourage.

The match is proof that better is possible

Before 1952, the residency market was in turmoil.[6] Hospitals made offers earlier and earlier, sometimes years before residency would begin, because moving first meant locking in preferred candidates. Applicants delayed commitments to gather more information, creating an unstable standoff: exploding offers with 48-hour deadlines, coercive pressure, and widespread misery on both sides. The original NRMP algorithm brought order, but it was hospital-proposing: hospitals made offers according to their preferences; students accepted or rejected. This systematically favored hospitals. Worse, students could sometimes game the system by misrepresenting their preferences, ranking a less-preferred program higher if they believed that program had ranked them highly.[1] By the 1990s, changes in the residency market had exposed limitations in the existing algorithm. Couples seeking positions in the same city could not be accommodated.[1] Students and advocacy organizations increasingly questioned why the mechanism favored hospitals.

Roth's redesign made one elegant change: reverse who proposes.[1] Students now make offers to programs according to student preferences. This seemingly minor adjustment made the mechanism strategy-proof for students. Applicants could rank programs according to their true preferences without sacrificing their chances of a favorable match. The cognitive burden of gaming the system disappeared entirely. Students could focus on genuine evaluation of fit. The Match works because economists who understood strategic behavior designed it deliberately to achieve specific properties such as stability, applicant-oriented incentives, and practical accommodation of couples. It works because someone actually thought about what game they were creating. Most medical education policies emerge from committees that have never heard of mechanism design. The resulting policies often reward behavior that conflicts with their stated goals.

Grading systems are where good intentions go to die

Traditional letter grading with curves creates zero-sum competition. One student's A is another student's B. The competition follows directly from the grading system. The incentives to withhold information, avoid helping peers, and engage in strategic sabotage are baked into the structure. Medical schools did recognize this problem, and most have now adopted pass/fail grading, particularly in preclinical years, explicitly to reduce competition and foster cooperation.[7] The evidence that this works for the narrow goal of reducing grade-related stress is robust. Pass/fail grading reduces anxiety and burnout while improving psychological well-being, with no decline in licensing exam performance.[8,9]

Pass/fail grading reduced competition over course grades while increasing the importance of other measures used to distinguish applicants. With grades no longer differentiating students, residency programs turned to other metrics: research productivity, away rotations, letters of recommendation, Step 2 Clinical Knowledge (CK) scores. Students responded exactly as game theory would predict. The average successful residency applicant in 2022 had three times as many research publications as applicants in 2009.[10] That threefold increase over little more than a decade reflects a substantial escalation in credential-based competition. The "shadow economy" of credential-building has created new pressures and arguably new harms. Students churn out research of questionable educational or scientific value, projects designed not to advance knowledge but to pad curriculum vitae. The result was a broader and more demanding form of competition centered on credential accumulation. A 2021 analysis by Warm and colleagues identified issues embedded in the residency match ecosystem.[11] Each deserves examination, because each reveals how well-intentioned actors, responding rationally to local incentives, collectively produce outcomes that serve no one.

The medical school evaluation dilemma

Medical schools could cooperate by providing honest, comprehensive assessments, including student weaknesses and areas requiring growth. This would give residency programs useful information for making appropriate placements, but let us consider the incentives. If some schools provide inflated evaluations while others offer honest assessments, students from honest schools are systematically disadvantaged. The school that tells the truth watches its students get passed over for candidates from schools willing to lie, so everyone lies. The dominant strategy becomes grade inflation and uniformly glowing recommendation letters.

The result is that recommendation letters carry almost no informational value. Program directors report that nearly all letters are positive to the point of uselessness.[11] When nearly every applicant is described as exceptional or ranked in the top ten percent, those distinctions no longer help programs differentiate among candidates. This forces programs to rely on crude quantitative metrics like USMLE Step 1 and 2 CK scores, which may correlate poorly with clinical competence but at least differentiate candidates. The system designed to identify the best matches instead optimizes for test-taking ability.

This is classically a Nash equilibrium. Schools providing honest evaluations would unilaterally harm their students without improving the system. The only escape is coordinated change, with all schools shifting simultaneously to honest assessment practices. Without that coordination, the equilibrium persists: what remains rational for each participant continues to produce a worse outcome for all.

The residency interview dilemma

Residency programs could cooperate by limiting interviews to reasonable numbers, perhaps two to three times available positions. This would reduce burden on programs, decrease costs for applicants, and potentially improve interview quality. But if some programs interview extensively while others limit, the extensive interviewers access a broader candidate pool.[11] What program director wants to explain to their department chair that they missed a star candidate because they unilaterally "disarmed" while competitors kept interviewing?

Consequently, everyone interviews excessively. Some competitive specialties interview ten to fifteen times their available positions. Students fly all over the country during interview season, spending money they do not have, missing clinical rotations that actually matter for their education. Programs spend enormous faculty time on interviews that provide diminishing marginal information after the first dozen. The process has become a logistical nightmare for all parties involved. Match

quality has not improved, but no individual program can afford to limit interviews when competitors maintain high numbers. The prisoner's dilemma structure makes defection (extensive interviewing) individually rational even as it produces collective harm.

The curriculum disengagement dilemma

Medical schools invest enormous resources in curriculum design. Faculty spend countless hours developing educational experiences intended to cultivate clinical reasoning, professionalism, and foundational understanding. Meanwhile, students sit in lectures reviewing question banks on their laptops.[12,13] The expansion of First Aid for the USMLE Step 1 is an obvious example. The dominant commercial study resource has approximately doubled in length over the past 25 years, from roughly 400 to 800 pages. This is an arms race in content coverage, driven by competitive pressure that has nothing to do with educational value. In parallel, examination standards have risen over the same period. When Step 1 transitioned to pass/fail in January 2022, the minimum passing standard increased. Step 2 CK passing scores rose from 209 (pre-2014) to 214 (2022) to 218 (2025). Meanwhile, average scores climbed even faster. The mean Step 2 CK score reached 249 in 2023–2024, a 50-point increase over three decades.[14]

From a game theory perspective, students face a strategic choice: engage deeply with institutional curricula or prioritize commercial board preparation. If all students prioritized curriculum engagement, collective educational outcomes would improve. However, if some students prioritize board scores while others engage with curricula, the board-focused students gain competitive advantage in the match.[15] Under these conditions, board preparation becomes the dominant strategy, while the institutional curriculum loses student attention and educational influence. The Step 1 transition to pass/fail was intended to reduce this pressure, yet the incentives driving it remained unchanged. Competition shifted to Step 2 CK, whose average scores for matched applicants now stand at 250 and rising, and research expectations escalated. The fundamental problem (students competing for limited residency positions while programs need differentiation mechanisms) remained untouched.[15] This outcome was entirely predictable. Removing one metric for differentiation without coordinating how programs evaluate applicants simply shifts competition to remaining metrics. Programs still need ways to rank hundreds of applicants. Students therefore continue to seek whatever distinctions remain available, shifting competition from one set of credentials to another while leaving its underlying incentives intact.

Systemic implications

These prisoner's dilemmas interact and reinforce each other. The system has settled into a stable but spectacularly inefficient equilibrium. First Aid continues to expand, even as lecture attendance falls. Rising Step 2 CK scores have not been accompanied by comparable gains in clinical skills. Students build larger research portfolios, yet genuine scholarly engagement declines. Recommendation letters offer little differentiation, and additional interviews consume faculty and applicant time without improving match quality. More resources are therefore devoted to accumulating and evaluating credentials that provide little useful information. Each actor responds rationally to local incentives, and each individual decision makes sense in isolation. Taken together, however, those decisions produce an inefficient system that imposes substantial costs on its participants.

Game theory suggests two primary paths out of prisoner's dilemmas. First, change the payoff structure so cooperation becomes the dominant strategy. This typically requires coordination, with all players changing simultaneously or bound by enforceable agreements. Second, create conditions where reputation effects and reciprocity sustain cooperation over time.

The current status quo of medical education has accomplished neither. The pass/fail interventions represent incomplete mechanism design. They correctly diagnosed that curved grading and Step 1 scores create competition, but they failed to address the underlying coordination problem: students still compete for limited positions, and programs still need differentiation mechanisms. Without redesigning the entire system, including how programs evaluate applicants, signal their criteria, and coordinate their practices, pass/fail grading only relocated competition.

Isolated interventions addressing symptoms of competition produce displacement effects. The NRMP succeeded because it was designed as a coordinated national mechanism with participation from all stakeholders. Most educational reforms fail to achieve similar

coordination, instead emerging from individual institutions acting independently in response to local pressures.

Principles for better design

First, systems create behaviors. When medical students compete in environments ostensibly designed for collaboration, the appropriate response is examining what game the system creates, not exhorting individuals to play differently. Students skipping lectures to study for board examinations are not failing morally. They are responding rationally to systems that reward examination performance over curriculum engagement. Blaming students for structural failures is lazy and counterproductive.

Second, mechanism design requires expertise and intention. The NRMP works because economists and computer scientists designed it deliberately to achieve specific properties. Most educational policies emerge from committees without any systematic analysis of strategic implications. Medical educators should either develop mechanism design literacy or consult with those who possess it. The alternative is continuing to create games that punish the behaviors we claim to value.

Third, strategy-proofness is important. Systems requiring participants to engage in complex strategic calculations waste cognitive resources and erode trust. The Match demonstrates that mechanisms can be designed where honesty is the dominant strategy. Evaluation systems could aspire to similar properties, where revealing uncertainty and asking questions serves students' interests rather than creating evaluation risks.

Fourth, isolated interventions produce displacement effects. Pass/fail grading reduced grade competition but shifted competition to research. Step 1 scoring changes shifted emphasis to Step 2. Policies must anticipate how changing one dimension affects others. Comprehensive system redesign works better than incremental patches.

Fifth, coordination mechanisms are essential. Prisoners' dilemmas cannot be solved through individual action. Solving them requires changing payoffs for all players simultaneously or creating enforceable agreements. This demands coordination across institutions, which requires national-level mechanisms or strong professional organization involvement.

Implementation faces substantial challenges. Coordination requires collective action across autonomous institutions. Preventing further displacement will require programs to revise how they evaluate applicants. Examination bodies should align test content with educational goals, and faculty will need new approaches to assessment. Reform may also face resistance from students who benefit from the current competitive system. These barriers make change difficult, but they do not place it beyond reach. The NRMP demonstrates that coordinated redesign is possible.

Final remarks

Application of game theory warrants discussion about its limitations. It assumes a rationality that humans only approximate. Many physicians genuinely value patient welfare independent of incentive structures. People cooperate even when defection is optimal, driven by ethics, empathy, and professional identity.[16] Medicine benefits from attracting individuals with strong prosocial motivations. Game theory is most useful here as a tool for reinforcing medicine's humanistic commitments. It can help design structures that allow those commitments to guide behavior without placing the people who follow them at a strategic disadvantage.

Currently, medical education asks students to maintain collaborative values while navigating competitive structures. This works for some individuals deeply committed to values despite disadvantages, but it does prove unsustainable for populations. Better design makes cooperation easier, allowing prosocial motivations to flourish rather than being continuously suppressed by structural incentives toward competition.

Medical education also depends on mentorship and the examples set by physicians, both of which shape how students develop their professional identities in ways that game theory cannot fully capture. Students learn from observing how attending physicians handle uncertainty, treat colleagues, and prioritize competing demands. These elements matter profoundly and cannot be captured by mechanism design alone. Viewed through game theory, medical education contains a fundamental contradiction between the values it teaches and the incentives it creates. Schools ask future physicians to prioritize teamwork and collective welfare. Yet trainees are evaluated within systems that tie personal advancement to outperforming peers, sometimes giving them reason to withhold information that a collaborative environment would encourage them to share. Culture and character offer only a partial explanation for these recurring dysfunctions. Their persistence reflects incentive structures

that emerged inadvertently as policies accumulated without coherent guiding principles.

The residency match demonstrates what becomes possible with thoughtful design. An algorithm created by economists who understood that strategic behavior produces stable, strategy-proof matches for over 40,000 applicants annually.[17] Students focus on genuine evaluation of fit rather than gaming the system, because the mechanism makes honesty optimal. The challenge is extending this sophistication to other domains: grading, assessment, curriculum engagement, clinical evaluation, interview processes, examination systems, research expectations. Extending that approach requires medical educators to examine how institutional incentives shape behavior and whether they align with the values taught in the curriculum. Well-intentioned reforms remain vulnerable to predictable failure when their strategic effects are left unexamined.

The goal is designing systems where the Nash equilibrium aligns with collaborative values. Within such a system, students could reveal their preferences honestly because doing so would produce the best available outcome. Deep engagement with the curriculum would also advance their competitive interests, and seeking help would strengthen their evaluations without carrying a strategic penalty. Cooperation would then become the dominant strategy and offer students the strongest path to individual success. Medicine has solved one complex coordination problem through mechanism design. The task now is bringing similar rigor to the broader educational ecosystem, creating structures worthy of the values medicine claims to embody. This requires moving beyond exhortations for better individual behavior toward systematic redesign of the games medical education asks its participants to play.

References

1. Roth AE, Peranson E. The redesign of the matching market for American physicians: some engineering aspects of economic design. *American Economic Review.* 1999;89(4):748–80.
2. Nobel Prize Outreach AB. The Prize in Economic Sciences 2012. *NobelPrize.org.* 2012. Accessed September 18, 2026. https://www.nobelprize.org/prizes/economic-sciences/2012/summary/
3. Rapoport A, Chammah AM. *Prisoner's Dilemma: A Study in Conflict and Cooperation.* Ann Arbor, MI: University of Michigan Press; 1965.
4. Nash JF. Equilibrium points in n-person games. *Proceedings of the National Academy of Sciences of the United States of America.* 1950;36(1):48–9.
5. Roth AE. The economist as engineer: game theory, experimentation, and computation as tools for design economics. *Econometrica.* 2002;70(4):1341–78.
6. Roth AE. The evolution of the labor market for medical interns and residents: a case study in game theory. *Journal of Political Economy.* 1984;92(6):991–1016.
7. Association of American Medical Colleges. *Medical School Graduation Questionnaire: 2016 All Schools Summary Report.* Washington, DC: Association of American Medical Colleges; 2016.
8. Spring L, Robillard D, Gehlbach L, Moore Simas TA. Impact of pass/fail grading on medical students' well-being and academic outcomes. *Medical Education.* 2011;45(9):867–77.
9. Bloodgood RA, Short JG, Jackson JM, Martindale JR. A change to pass/fail grading in the first two years at one medical school results in improved psychological well-being. *Academic Medicine.* 2009;84(5):655–62.
10. National Resident Matching Program. *Charting Outcomes in the Match: Characteristics of Applicants Who Matched to Their Preferred Specialty in the 2022 Main Residency Match: Senior Students of U.S. MD Medical Schools.* Washington, DC: National Resident Matching Program; 2022.
11. Warm EJ, Kinnear B, Pereira A, Hirsh DA. The residency match: escaping the prisoner's dilemma. *Journal of Graduate Medical Education.* 2021;13(5):616–25.
12. Chen DR, Priest KC, Batten JN, Fragoso LE, Reinfeld BI, Laitman BM. Student perspectives on the "Step 1 climate" in preclinical medical education. *Academic Medicine.* 2019;94(3):302–4.
13. Burk-Rafel J, Santen SA, Purkiss J. Study behaviors and USMLE Step 1 performance: implications of a student self-directed parallel curriculum. *Academic Medicine.* 2017;92(11S):S67–74
14. United States Medical Licensing Examination. Performance data and passing standards. Accessed October 23, 2025. https://www.usmle.org/performance-data
15. National Resident Matching Program. *Charting Outcomes: Program Director Survey Results, 2024 Main Residency Match.* Washington, DC: National Resident Matching Program; 2024.
16. Colman AM. Cooperation, psychological game theory, and limitations of rationality in social interaction. *Behavioral and Brain Sciences.* 2003;26(2):139–153.
17. National Resident Matching Program. *Results and Data: 2024 Main Residency Match.* Washington, DC: National Resident Matching Program; 2024.