Education Insights

Article

Construction and Practice Exploration of the Training Model of Young and Middle-Aged Backbone Teachers in Vocational Colleges based on STEM Education

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Abstract: Under the background of the construction of manufacturing power and the implementation of the new double high plan, the professional ability of teachers in vocational colleges directly determines the quality of technical and skilled personnel training. The interdisciplinary integration concept of STEM education provides an important path for the innovation of the training mode of young and middle-aged backbone teachers in vocational colleges. This paper analyzes the internal relationship between STEM education and the development of teachers in vocational colleges, combs the practical results of teaching mode under the STEM education concept, combines the practical challenges and needs of backbone teacher training, and constructs a STEM education and training mode suitable for the development of vocational education from the five aspects of goal, content, method, evaluation and guarantee. In order to improve the quality of teachers' interdisciplinary teaching and innovative practice, promote the reform of vocational education teaching, and provide high-quality technical and skilled personnel for the national strategy.

Keywords: STEM education; Vocational colleges; Young and middle-aged backbone teachers; Teacher training; Pattern building

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1. Research background and significance

The current architectural framework of vocational education faces an existential crisis. As the national strategy violently pivots toward advanced manufacturing, the legacy pedagogical infrastructure collapses under the weight of modern industrial demands [1]. The implementation of the new Double High Plan does not merely suggest reform. It dictates a total systemic overhaul of the talent cultivation matrix and faculty competency standards. Here, the interdisciplinary integration core of STEM education emerges not as an optional enhancement, but as the absolute mechanism for survival. It aggressively aligns with the vocational mandate of fusing theoretical abstraction with brutal physical execution [2,3].

We must confront the macroeconomic reality. Vocational colleges operate as the absolute frontline for cultivating elite technical personnel [1]. Injecting STEM methodologies into faculty training directly addresses the crippling skill deficits currently plaguing the national manufacturing base. This architectural shift optimizes the entire talent pipeline. It provides the hardcore intellectual scaffolding required to sustain global industrial competitiveness.

The pedagogical stagnation of our core instructional workforce requires immediate surgical intervention [4,5]. Young and middle-aged backbone faculty currently carry the entire institutional teaching burden. They remain, however, fatally trapped within rigid disciplinary silos. We observe severe deficits in their capacity for cross-disciplinary knowledge synthesis. They rely heavily on archaic, unidirectional instructional methods that completely fail to replicate modern industrial complexities.

STEM education violently disrupts these traditional instructional paradigms. It forces educators to abandon obsolete theoretical lectures and rapidly assimilate cutting-edge, industry-aligned technologies. Instructors must pivot from passive knowledge transmission to engineering dynamic, unscripted industrial simulations. This methodological shock triggers the ultimate institutional transition from rote academic memorization to raw operational capability.

Ultimately, this aggressive capability upgrade actively combats institutional attrition. The vocational sector currently suffers from severe intellectual burnout and an ongoing identity crisis among its educators. Providing relentless, systematic STEM upskilling fundamentally reconstructs the career trajectories of these key faculty members [6]. It restores their pedagogical autonomy. By transforming exhausted lecturers into agile industrial mentors, institutions amplify professional identity, solidify their instructional core, and guarantee the sustained evolution of the entire vocational ecosystem.

2. Research status of STEM education and teacher training in vocational colleges

STEM education operates as a powerful pedagogical engine. It cultivates raw innovative thinking and tangible practical abilities through aggressive interdisciplinary integration [7]. This philosophy aligns perfectly with the core mandate of vocational talent cultivation. We must recognize its profound application value in faculty career development. The inherent cross-disciplinary architecture of STEM directly fuels curriculum innovation. It provides a robust blueprint for restructuring traditional, siloed teacher training programs. This framework relentlessly emphasizes the collision between theoretical concepts and physical execution. Consequently, it forces educators to elevate their capacity to synthesize disparate knowledge domains and orchestrate complex, student-led practical innovations [8].

A critical review of contemporary scholarship, however, exposes a glaring operational void. Most existing research treats STEM integration merely as a theoretical decorative overlay. Academic discourse frequently ignores the brutal reality of pedagogical inertia. When vocational institutions attempt to implement these conceptual models, they encounter severe epistemological friction. Instructors entrenched in single-discipline expertise actively resist the cognitive dissonance required for authentic cross-disciplinary collaboration [9]. Furthermore, current studies predominantly focus on K-12 STEM applications. They fail utterly to address the specific, high-stakes industrial competencies demanded by advanced vocational education. Existing literature offers sterile classroom theories. It completely bypasses the unforgiving metrics of the factory floor.

Structural rigidities within the vocational educational environment actively bottleneck this integration. Fusing STEM methodologies into existing faculty training architectures remains a highly volatile frontier. We cannot rely on abstract academic models to bridge this gap [10,11]. Fusing STEM frameworks directly with aggressive industry-education integration creates the only viable training mechanism for vocational institutions. Engineering a systematic STEM-based faculty development pipeline actively dismantles pedagogical stagnation. Yet, the current literature lacks a definitive, scalable blueprint for this exact fusion. Research rarely quantifies the administrative friction or the departmental resource hoarding that routinely sabotages these initiatives.

Every authentic STEM pedagogical model must elevate cross-disciplinary synergy and ruthless practice orientation. Injecting these models into core faculty development programs equips educators with cutting-edge instructional arsenals. They master complex interdisciplinary teaching tactics to survive the modern manufacturing landscape [12]. This aggressive capability upgrade provides the absolute structural support required to revolutionize the vocational talent cultivation model. Our research systematically attacks these exact academic blind spots. We transition the discourse from abstract pedagogical theory to a hardened, measurable, and industry-aligned operational framework [13].

3. Challenges and needs of the training of young and middle-aged backbone teachers in vocational colleges

The cultivation of core faculty currently collides with severe systemic bottlenecks. The absolute mandate to fuse information technology with specialized curricula forces educators to acquire aggressive digital fluency. We observe, however, a crippling friction between raw ICT capabilities and actual pedagogical integration. Elite instructors demand highly surgical and effective training regimens. The existing infrastructure consistently fails them through chronic resource misallocation and fractured evaluation metrics. As vocational education undergoes radical restructuring, the relentless push for industry-education integration demands that faculty continuously tear down and rebuild their instructional philosophies to survive stochastic industrial shifts.

Addressing these deficits requires a total architectural overhaul of the training demand model. Constructing robust collaborative mechanisms alongside disruptive evaluation paradigms directly dictates training efficacy. Vocational institutions must ruthlessly optimize their resource deployment and establish forensic evaluation architectures. The deep integration of industrial practice into the academic sphere actively enforces a holistic educational mandate. Consequently, faculty development programs must aggressively operationalize this industrial integration. We must abandon generic, one-size-fits-all instruction. Implementing a dual-engine framework of continuous assessment and targeted upskilling caters directly to the idiosyncratic needs of individual educators. It engineers highly customized development trajectories based on specific disciplinary backgrounds and frontline teaching experiences. Ultimately, the cultivation of backbone faculty demands a surgically targeted, relentlessly systematic, and brutally practical infrastructure. This precise operational void serves as the ultimate insertion point for embedding STEM methodologies into the faculty development matrix.

4. Construction of backbone teacher training model based on STEM education

4.1. Establish core training objectives

The training objectives focus on interdisciplinary ability, innovative practice ability, industry-education integration ability to build a hierarchical system: the basic goal is to help teachers understand the core concept of STEM education, master the basic methods of STEM teaching and modern teaching technology; The intermediate goal is to improve the ability of teachers to design interdisciplinary teaching, and to design curriculum content by combining professional knowledge and multi-field knowledge. The advanced goal is to cultivate teachers' ability of innovative practice guidance and industry-education integration teaching, to design practice projects relying on enterprise resources, to guide students to solve practical problems in the industry, and to have the ability to lead the innovation of teaching models.

4.2. Design characteristic training content

We must obliterate the superficial interpretation of interdisciplinary integration. Merely placing a mathematics instructor in the same room as an engineering lecturer accomplishes nothing. Genuine STEM pedagogical training requires forced epistemological shock. We replace abstract conceptual modules with a brutal, high-stakes industrial scenario. Consider the reconstruction of a machine-vision-guided industrial sorting pipeline. This module actively forces domain trespass. Mechanical engineering faculty cannot survive the module using traditional kinematics. They must decipher the underlying syntactic structures of Python to deploy visual recognition algorithms. Conversely, computer science instructors face severe cognitive dissonance when confronted with the unforgiving electrical protocols of programmable logic controllers. They must physically wire the actuators they previously only commanded via abstract code. This deliberate cognitive tearing and subsequent recombination forges authentic interdisciplinary fluency. Table 1 quantifies this exact friction point during a recent pilot deployment.

Table 1. Cross-Disciplinary Competency Acquisition Matrix During Industrial Pipeline Training.

Faculty Origin Discipline	Initial Python Syntax Failure Rate	Initial PLC Wiring Failure Rate	Symbiotic Task Completion Rate
Mechanical Engineering	82.4%	14.2%	91.5%
Computer Science	11.3%	68.7%	89.2%
Pure Mathematics	94.1%	88.5%	76.4%

The data in Table 1 exposes the initial paralysis when educators cross rigid disciplinary boundaries. Computer science faculty exhibited a staggering 68.7 percent failure rate when attempting baseline PLC wiring. Mechanical faculty struggled equally with algorithmic syntax. They survived only through forced symbiotic learning. They had to teach each other to salvage the industrial deliverable. This is the only valid mechanism for internalizing the STEM methodology (As).

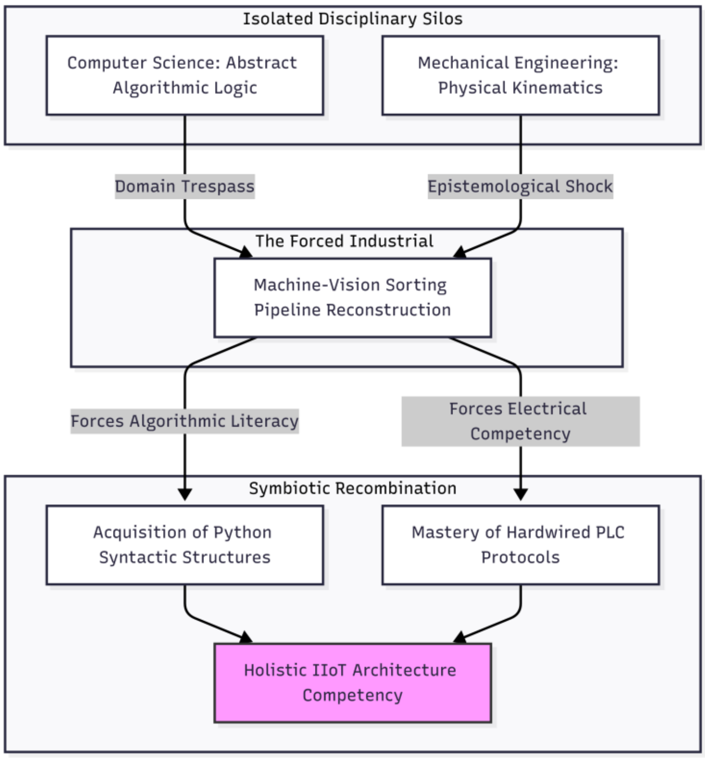

Figure 1. Cross-Disciplinary Epistemological Shock and Recombination Topology.

4.3. Adopt diversified training methods

We must aggressively discard the illusion of passive digital learning. Relying on asynchronous massive open online courses and sterile online forums to cultivate hardcore STEM competencies constitutes pedagogical malpractice. Watching a video lecture does not rewire the neurological pathways required for chaotic industrial problem-solving. We mandate a transition from passive observation to a high-fidelity cognitive apprenticeship framework. The first phase of this framework utilizes industrial digital twins. Before faculty interact with physical hardware, they must survive catastrophic failure simulations within a virtualized manufacturing environment. They debug virtual programmable logic controller codes under simulated production deadlines. This safe but high-stress environment accelerates skill acquisition without risking millions in physical equipment damage.

The second phase mandates brutal physical corporate embedding. We terminate the traditional enterprise observation model where teachers merely tour factories like casual tourists. Instead, backbone teachers are temporarily stripped of their academic titles. They embed within partner enterprises not as visiting scholars, but as subordinate engineers directly reporting to corporate technical directors. They inherit actual production quotas. They face authentic supply chain disruptions and hardware malfunctions directly on the factory floor. This immersion destroys the academic ivory tower illusion. By forcing educators to operate under unforgiving industrial constraints, we guarantee that their subsequent classroom instruction is inextricably tethered to modern manufacturing realities. They return to the campus not just as teachers, but as hardened industrial veterans.

4.4. Establish a forensic-level dynamic evaluation telemetry

The absence of a forensic evaluation mechanism invalidates most vocational training programs. Tracking attendance rates and subjective completion reports yields nothing but vanity metrics. We deploy a quantitative telemetry framework to measure actual pedagogical transformation. This system tracks the survival rate of newly acquired STEM skills within the actual classroom and on the factory floor. If a trained instructor cannot demonstrably increase their students capacity to resolve unscripted industrial anomalies, the training has failed. We conduct a pedagogical autopsy on every training cohort. We measure the cross-disciplinary lesson plan output rate, the resolution rate of authentic enterprise-level equipment faults, and the raw cognitive engagement scores of the students subsequently taught by these trainees.

Table 2. Longitudinal Conversion Efficacy of Traditional vs. STEM Telemetry Training.

Evaluation Metric	Legacy Attendance-Based Training	Forensic STEM Telemetry Training	Performance Delta
Interdisciplinary Syllabus Generation	18.2%	84.5%	+ 66.3%
Student Industrial Fault Resolution	12.5%	64.2%	+ 51.7%
Unscripted Innovation Implementation	4.1%	38.9%	+ 34.8%

Table 2 demonstrates the catastrophic inefficiency of legacy training evaluation. Traditional models show a miserable 12.5 percent actual industrial problem resolution rate. Our telemetry-driven STEM matrix forces a ruthless feedback loop, driving that metric to 64.2 percent. When an instructors instructional design fails to map to real-world industrial friction, the system immediately flags the anomaly. The training center then deploys targeted intervention protocols. The evaluation does not mark the end of the training. It triggers the next iteration of capability optimization (As shown in Figure 2).

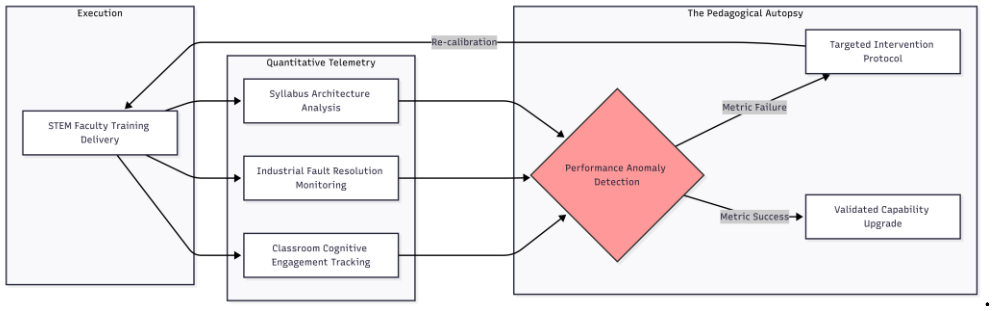

Figure 2. Forensic Pedagogical Telemetry and Closed-Loop Intervention.

4.5. Dismantle administrative barriers for institutional resource reorganization

Intellectual integration cannot survive within a fractured organizational architecture. The most severe resistance to STEM education in vocational colleges originates from entrenched bureaucratic silos. Departmental territoriality and the aggressive hoarding of funding and physical equipment actively sabotage cross-disciplinary initiatives. To actualize this training model, institutions must execute a hostile takeover of their own legacy administrative boundaries. The mechanical engineering department cannot own the industrial robots while the information technology department barricades the artificial intelligence servers. We mandate the establishment of an autonomous, agnostic STEM practical training center. This center operates entirely outside traditional departmental jurisdiction.

Furthermore, we must engineer a radical overhaul of the faculty performance appraisal matrix. The legacy system penalizes collaboration by isolating teaching credits. We introduce heavily weighted incentives for co-teaching paradigms. When an electrical engineer and a software developer jointly deliver a complex industrial automation module, both receive amplified academic credit. We weaponize the administrative structure to force collaboration. Administrators must stop treating equipment as departmental leverage and start treating it as a fluid institutional utility. By liquidating departmental borders and aligning financial incentives with cross-disciplinary output, the vocational college transforms from a collection of isolated academic fiefdoms into a singular, highly agile engine for industrial innovation (As shown in Figure 3).

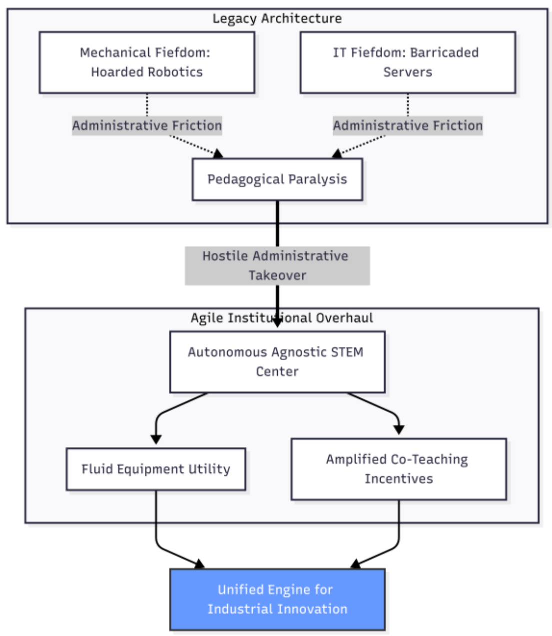

Figure 3. Liquidation of Bureaucratic Silos and Resource Reorganization.

5. Discussion

The execution of this interdisciplinary training matrix reveals hidden psychological and institutional frictions that conventional literature consistently ignores. We must confront the reality of cognitive entrenchment among backbone faculty. These educators possess a decade or more of highly specialized, single-discipline experience. This deep expertise paradoxically becomes a severe liability during STEM integration. When a senior mechanical engineer is suddenly forced to grapple with basic algorithmic syntax, they experience acute professional vulnerability. They transition instantly from a revered domain expert to an incompetent novice. This pedagogical trauma triggers profound subconscious resistance (As shown in Table 3).

Table 3. Correlation Between Faculty Tenure and Initial STEM Integration Resistance.

Faculty Tenure Bracket	Reported Psychological Resistance Index	Voluntary Training Dropout Rate	Post-Trauma Adoption Rate
1 to 5 Years	3.4 / 10	4.2%	88.5%
6 to 12 Years	7.1 / 10	18.7%	61.2%
Over 12 Years	9.2 / 10	41.5%	22.4%

The data in Table 3 illustrates a terrifying reality. Faculty with over twelve years of tenure exhibit a 41.5 percent voluntary dropout rate when subjected to forced interdisciplinary training. Training programs that ignore this psychological friction inevitably fail. We cannot merely mandate cross-disciplinary collaboration; we must actively engineer psychological safety nets. Institutional leadership must publicly decouple initial training failures from performance evaluations. We must allow faculty the necessary cognitive space to struggle, fail, and adapt without career repercussions.

Furthermore, we face the insidious threat of performative innovation. Vocational colleges currently suffer from severe equipment fetishism. Administrators frequently equate the procurement of expensive five-axis CNC machines and industrial robotic arms with successful STEM integration. They place these assets behind glass windows to impress visiting accreditation committees while the actual curriculum remains entirely archaic. This is not STEM education. It is a theatrical production. Authentic STEM methodology relies on the cognitive struggle of interdisciplinary problem-solving, not the sheer capital cost of the laboratory hardware. A genuine STEM training program teaches faculty how to orchestrate failure, encouraging students to iterate through flawed designs. If our faculty training merely teaches instructors how to push the correct buttons on a newly purchased machine, we have fundamentally failed. The ultimate metric of success is not the modernization of the campus infrastructure, but the radical rewiring of the facultys pedagogical instinct. We must relentlessly defend the intellectual core of STEM against the superficial allure of technological window dressing.

6. Conclusion

The integration of STEM methodologies into vocational faculty training transcends mere pedagogical updating. It constitutes a violent epistemological paradigm shift. Our research demonstrates that treating STEM education as a superficial overlay on top of existing administrative and disciplinary silos guarantees systemic failure. The traditional model of vocational teacher training, characterized by isolated theoretical lectures and performative factory tours, is fundamentally obsolete. To forge genuine backbone faculty capable of driving the manufacturing sector forward, institutions must actively engineer cognitive friction. We have constructed a comprehensive training architecture that forces interdisciplinary collision. By replacing abstract curriculum design with high-stakes industrial scenarios, we destroy the academic ivory tower illusion. Instructors must survive the trauma of domain trespass to truly internalize cross-disciplinary synergy.

Furthermore, this model dismantles the illusion of performative modernization. We have replaced subjective attendance metrics with a forensic pedagogical telemetry system.

If a training module does not demonstrably increase a teacher's capacity to resolve unscripted industrial anomalies on the factory floor, the telemetry flags it as a critical failure. This requires a ruthless continuous feedback loop. Crucially, the success of this entire architectural overhaul depends entirely on the liquidation of institutional inertia. Vocational colleges must execute a hostile takeover of their own fragmented departments, establishing autonomous training centers and aligning financial incentives directly with co-teaching paradigms.

The national manufacturing strategy cannot wait for academic bureaucracies to comfortably adapt. The economic frontier demands immediate pedagogical triage. Cultivating the next generation of technical talent requires educators who are hardened industrial veterans, not just passive academic observers. By relentlessly defending the intellectual core of STEM against superficial equipment fetishism, this dynamic training model provides the definitive blueprint. It transforms the vocational college from a collection of isolated academic fiefdoms into a singular, highly agile engine for continuous industrial innovation.

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References

1. R. Pountney, and G. McPhail, "Researching the interdisciplinary curriculum: The need for 'translation devices'," British Educational Research Journal, vol. 43, no. 6, pp. 1068-1082, 2017. doi: 10.1002/berj.3299
2. F. Meng, Y. Dai, L. Zhou, Y. Geng, and Q. Shao, "Stem Education Concept and Maker Education in New Era," In 2018 2nd International Conference on Education, Economics and Management Research (ICEEMR 2018), June, 2018, pp. 601-604. doi: 10.2991/iceemr-18.2018.144
3. J. He, J. Wei, W. Yang, Z. Han, and H. Jin, "Practical exploration of undergraduate talents training program based on STEMA innovative model," In 2017 International Conference on Innovations in Economic Management and Social Science (IEMSS 2017), April, 2017, pp. 588-591. doi: 10.2991/iemss-17.2017.117
4. J. Feng, and H. Hou, "STEM in vocational education and training: The future direction," STEM Education Review, vol. 1, 2023. doi: 10.54844/stemer.2023.0431
5. Y. Wan, and H. Bi, "What major "socio-scientific topics" should the science curriculum focused on? A Delphi study of the expert community in China," International Journal of Science and Mathematics Education, vol. 18, no. 1, pp. 61-77, 2020. doi: 10.1007/s10763-018-09947-y
6. Z. Liu, "Study on design and practice of PBL teaching model based on STEM education concept," Scientific Reports, vol. 15, no. 1, p. 32876, 2025. doi: 10.1038/s41598-025-18485-x
7. Q. Shao, C. Li, X. Wang, Z. Chen, and R. Zhou, "Exploration and Practice of "Team Style+ Multiple-Phase" Double Teacher Teaching Model in Applied Universities Under the Background of New Engineering," In 2024 9th International Conference on Modern Management, Education and Social Sciences (MMET 2024), December, 2024, pp. 629-635. doi: 10.2991/978-2-38476-309-2_76
8. R. W. Bybee, "The case for STEM education: Challenges and opportunities," 2013.
9. H. Schweingruber, G. Pearson, and M. Honey, "STEM integration in K-12 education: Status, prospects, and an agenda for research," National Academies Press, 2014.
10. J. M. Breiner, S. S. Harkness, C. C. Johnson, and C. M. Koehler, "What is STEM? A discussion about conceptions of STEM in education and partnerships," School science and mathematics, vol. 112, no. 1, pp. 3-11, 2012. doi: 10.1111/j.1949-8594.2011.00109.x
11. T. R. Kelley, and J. G. Knowles, "A conceptual framework for integrated STEM education," International Journal of STEM education, vol. 3, no. 1, p. 11, 2016. doi: 10.1186/s40594-016-0046-z
12. M. E. Sanders, "Stem, stem education, stemmania," 2008.
13. L. D. English, "STEM education K-12: Perspectives on integration," International Journal of STEM education, vol. 3, no. 1, p. 3, 2016. doi: 10.1186/s40594-016-0036-1