Designing and implementing an AI education program for learners with diverse background at scale

Andres F. Salazar-Gomez
Open Learning
Massachusetts Institute of Technology
Cambridge, USA
salacho@mit.edu

Aikaterini Bagiati
Open Learning
Massachusetts Institute of Technology
Cambridge, USA
abagiati@mit.edu

Nicholas Minicucci
Open Learning
Massachusetts Institute of Technology
Cambridge, USA
nickmini@mit.edu

Kathleen D. Kennedy
Open Learning
Massachusetts Institute of Technology
Cambridge, USA
kdkenn@mit.edu

Xiaoxue Du
Media Lab
Massachusetts Institute of Technology
Cambridge, USA
xiaoxued@media.mit.edu

Cynthia Breazeal
Open Learning & Media Lab
Massachusetts Institute of Technology
Cambridge, USA
cynthiab@media.mit.edu

Abstract*—This Research to Practice Full Paper presents an AI Education program. In January 2021 MIT entered into an agreement with the United States Air Force (USAF) and the Department of Defense (DoD) to design and offer a new educational research program focusing on Artificial Intelligence (AI) training. The goal of this collaboration is to design and advance educational research activities that promote maximum learning outcomes at scale for learners with diverse roles and educational backgrounds, ranging from Air Force and DoD personnel to the general public. This program is expected to offer different learning tracks addressing different groups of USAF employees based on their unique professional needs and backgrounds. The first pilot is currently underway and will provide the research team with data and insights that will inform the next iteration of the program, with the ultimate goal of formulating recommendations for the USAF and general public on how to reach large numbers of learners at scale in an optimum way. Currently, the program offers three different learning journeys for each of three different cohorts of USAF employees (i.e., leaders, developers, and users). These learning journeys span from online asynchronous and synchronous courses to in-person activities. Our research goals focus on exploring and understanding the learner experience via the study and analysis of AI content and curriculum, pedagogical approaches, learning modalities, and technological innovations to deliver learning experiences at scale. Key research activities involve evaluating a range of existing digital AI courses, mapping out the landscape of educational needs and competencies, and developing and piloting experiential learning experiences (to advance innovative technology-enabled training and learning technologies and methods). This paper discusses how preliminary research findings from this first pilot are informing the design and implementation of the next program iteration. The research provides insights that will benefit AI learners across the US while supporting the DoD's objective to develop elite and world-class AI-ready services.

Keywords*—AI education, curriculum development, scalable education, diverse learners, competency development

I. Introduction

Artificial Intelligence (AI) is rapidly becoming the next frontier [1, 2]. It is a disruptive factor influencing and intersecting with every aspect of the public and private sectors. It presents opportunities and challenges to governments, industries and the public alike [3]. As a result, AI literacy and AI technological adoption are imperative at a global scale. However, AI is a relatively new field and AI education practices are still understudied, making AI education a complex task and one of the current challenges in engineering education. This is especially true when we consider the diverse background of members of our society, and the scale required for educational programs to reach large numbers efficiently.

Aware of these circumstances, the government of the United States of America developed a series of directives, acts and laws, including the 2018 Department of Defense Artificial Intelligence Strategy [4] and the National Defense Authorization Act for the fiscal year 2020, included in the US Congress Artificial Intelligence Education Strategy [5].

These directives highlight that "...there is a strategic imperative for the Department [of Defense] to adopt Artificial Intelligence (AI) at speed and at scale", and that "DoD must prioritize educating and training its incredibly diverse and talented workforce to deliver AI capabilities at scale across the Department.". In summary, for this agency "the future of AI in the DoD relies on the Department's ability to build and develop a workforce for the digital era".[6]. The Joint Artificial Intelligence Center (JAIC) unit was selected by DoD to carry out this task.

Following these developments, MIT, the Department of Defense (DoD) and the United States Air Force (USAF) entered into an agreement to design, offer and study a new educational program focusing on AI training for DoD and USAF personnel. The program discussed in this manuscript aims to design and employ educational research activities to explore optimum ways to offer AI education, online and in-person, to learners with diverse professional roles and with different educational backgrounds. The full body of USAF personnel is approximately 680.000 employees, with an educational background that spans from high school diploma to graduate degrees, so optimization regarding future scalability of the program is also a critical factor to be explored.

Ultimately this research collaboration aims to advance knowledge about state-of-the-art technology-enabled pedagogies and learning experiences about AI, and present

Supported by funding from the USAF Research Laboratory and the USAF Artificial Intelligence Accelerator under Cooperative Agreement Number FA8750-19-2-1000

research findings to guide similar AI training programs designed and offered to the general public.

II. Educational Research Program

This educational research program was designed particularly considering a set of specific learner profiles, learning objectives, and desired skills, mindsets and behaviors as defined in the 2018 Department of Defense Artificial Intelligence Strategy report [4]. The academic activities were structured to last approximately six to twelve months, with courses and events distributed throughout 2021. Due to the impact of COVID on in-person training, some courses and activities were delayed, and some cohorts only completed their courses in 2022.

When developing the learning journeys, it was critical for us, as well as in other AI training programs, to carefully contextualize the learning experience for the targeted learner population (learners profiles) [7]. Specifically, our proposed program diverts from previous AI training initiatives in that the population of learners has diverse professional roles and different educational backgrounds, while training was expected to reach a very large scale. This contrasts with most of the previous AI education programs, although not many yet exist, which have focused on a specific group of learners such as K-12 [7,8,9] or undergraduate students [10].

A. Learners profiles

As a starting point JAIC presented the MIT team with 6 particular learner profiles along with their distinct USAF roles, and a set of desired AI skills and competencies. Table I presents the learner profiles and their role and Fig. 1 summarizes, per archetype, the depth level of the AI topics and competencies (basic, intermediate, advanced), for the content and activities proposed in the program.

TABLE I. LEARNER PROFILES AND THEIR MAIN ROLE (TAKEN FROM [11])

Name	Role
Lead AI	Decides policy and doctrine, including how AI tools can or will be used; builds AI vision and plan
Drive AI	Ensures appropriate AI tools and capabilities are developed and delivered
Create AI	Creates AI tools to meet current and future needs
Embed AI	Embedded with Employ AI, establishes AI systems and provides end-user support at tactical edge
Facilitate AI	Represents user to ensure appropriate AI tools are developed and delivered to address use cases
Employ AI	End-user of AI tools, provide feedback on and requirements for AI tools.

B. Learning Journeys (cohorts)

Academic and research activities focused on the learning journeys of three main cohorts of learners for the six primary role archetypes. These cohorts are named Lead-Drive, Create-Embed and Facilitate-Employ. The Lead-Drive cohort consists of leaders and managers who set vision, strategy and lead execution and operations. The Create-Embed cohort consists of technical developers who acquire and develop technology-enabled capabilities and applications. The Facilitate-Employ cohort includes personnel that use technical solutions in their daily work activities and are the end users of AI technology [6]. This last cohort is expected to be the one mainly providing insights about scalability of the training program.

In summer of 2020 the program team developed a specialized learning journey specific to each cohort and their AI-related learning objectives. For the Lead-Drive cohort one hundred learners (100) were selected by the USAF and recruited to participate in AI and business strategy training. The Create-Embed cohort was designed to increase the learners' technical knowledge and know-how about developing AI solutions. For this cohort thirty (30) learners were recruited. The Facilitate-Employ cohort, comprised by one hundred (100) learners, were to receive training on the fundamentals of AI knowledge.

To craft these learning journeys, the program team curated digital courses and material on AI from the expansive AI catalog at MIT (inclusive of MIT Lincoln Laboratory) for all three cohorts. Some of these courses were then additionally tailored to fit the Lead-Drive and Create-Embed cohort needs, as presented in Fig.1 and 2.

A combination of different learning modalities was selected for each cohort. Across the learning journeys the courses and activities spanned from self-paced and instructor-led asynchronous online courses, synchronous online courses (with live lectures and presentations), live webinars, as well as in-person, hands-on experiential workshops. Fig.2 presents the courses and modalities per cohort. Each modality was studied separately.

The Lead-Drive cohort participated in a total of four (4) courses: two self-paced asynchronous, one online synchronous (for a subset of learners), and one in-person hands-on experiential workshop (for another subgroup of learners). Overall, the whole learning journey required approximately nine (9) months for completion. The Lead-Drive cohort was exposed to more hands-on, synchronous and in-person activities given their need for compact but intensive learning experiences, optimally suited to the time restrictions stemming from their USAF and DoD rank and responsibilities.

In the Create-Embed cohort learners could enroll in four to six (4-6) courses: two self-paced asynchronous, at least one instructor-paced asynchronous (with the option to take two more), and one in-person hands-on experiential workshop (offered to the whole cohort). The whole learning journey required twelve (12) months for completion. This learning journey included intensive instructor-led courses and one in-person experiential workshop due to the importance of highly technical and applied training in their USAF and DoD roles.

The Facilitate-Employ cohort was offered two (2) asynchronous self-paced courses that included over 10 hours of AI-related videos and readings. For this learning journey courses were expected to be completed in approximately 3 weeks, but the materials were available to the learners for a whole year. Learners were also invited to participate in a

series of live online events (see Fig. 2 for more details). Facilitate-Employ learners represent the vast majority of the USAF and DoD workers, so it was imperative to offer a learning journey with self-paced, asynchronous, activities that could eventually be scalable to hundreds of thousands of users (unachievable if the learning journey included in-person activities).

Besides the core content, all cohorts had access to six different live AI-focused webinars and optional self-paced asynchronous materials comprising more than 20 hours of complementary AI-related videos and readings. Table II presents a summary of the learning modalities and courses offered to each learning journey.

Following the design of the learning journeys, the AI Education Research portal was designed and used by the program team to provide learners access to the content. The portal works as a hub for all courses and activities, but learners access their courses by being re-routed to multiple delivery platforms. Fig. 3 presents the list of mandatory and optional courses and activities learners have access to when logging into the portal. Each learner had access only to a personal learning journey matching their archetype.

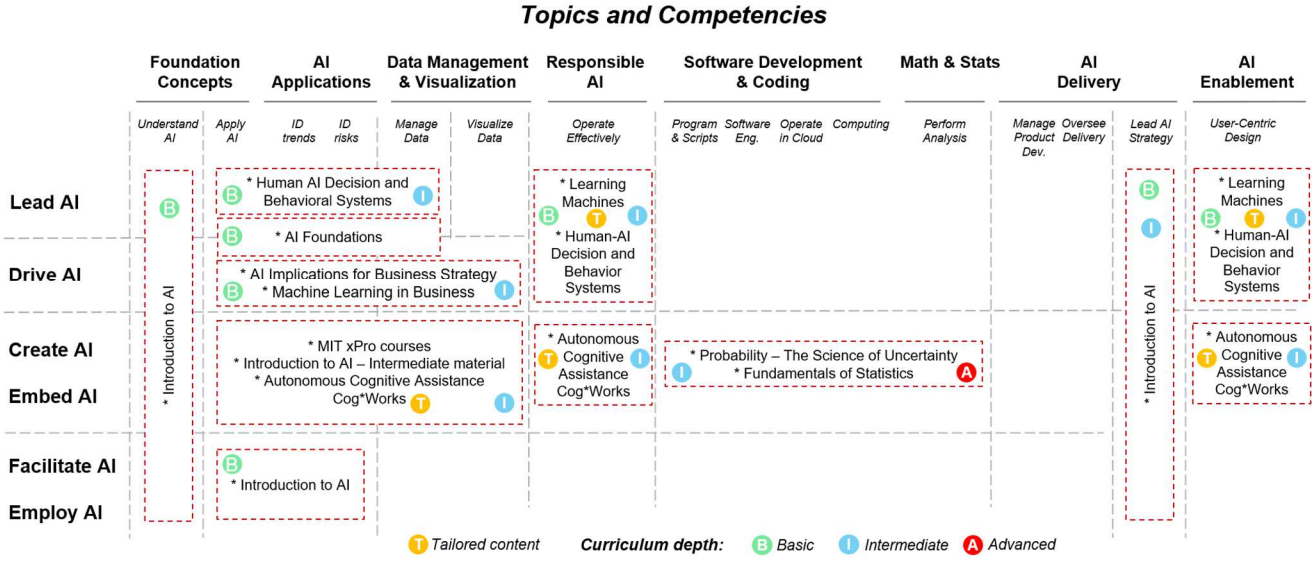

Fig. 1. Courses per archetype including the depth (basic B, intermediate I or advanced A) of the AI topics and competencies covered, including tailored content (T)

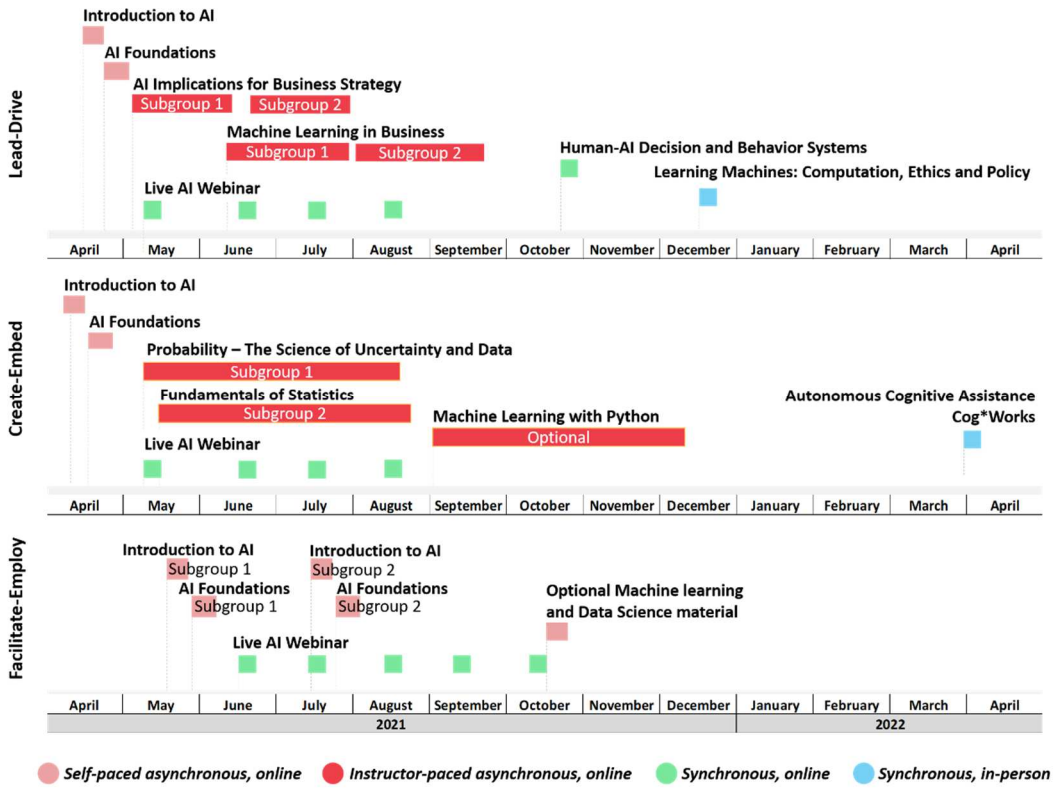

Fig. 2. Summary of the learning journeys (with courses and their modalities) for all three cohorts, across time (bar length represents length of the course or activity)

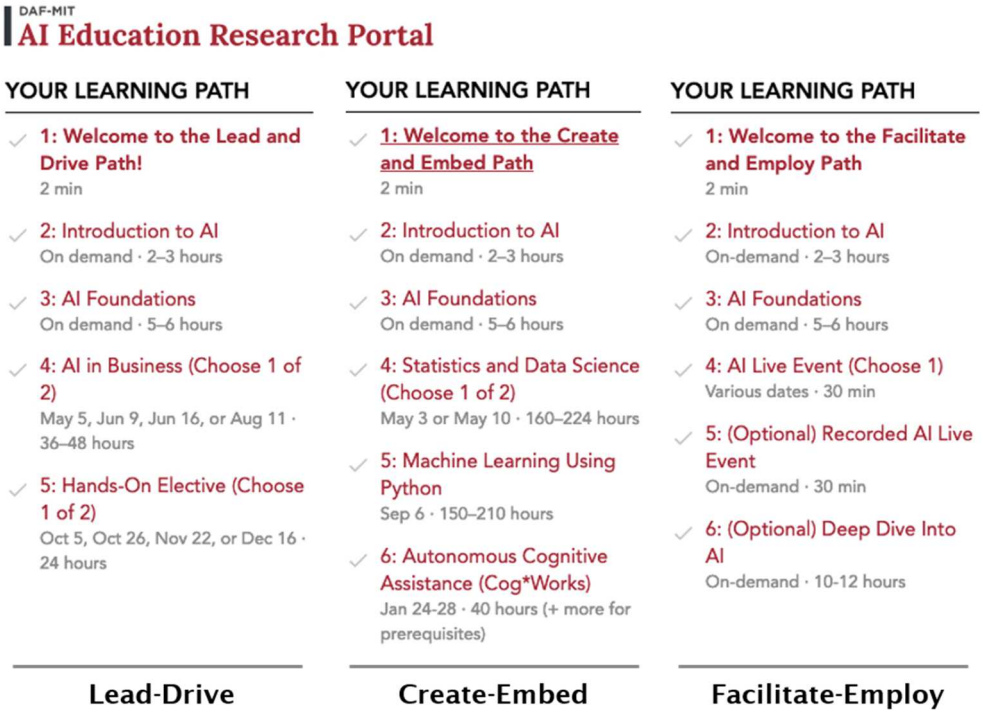

Fig. 3. AI Education Research portal presenting the courses covered in all three learning journeys. For more details on the learning journeys see Fig. 2 (taken from [11]

TABLE II. DISTRIBUTION OF LEARNING MODALITIES PER LEARNING JOURNEY (TAKEN FROM [11])

Cohort	Learning Journey content and activities (# of offerings)				
	Online self-paced asynchr.	***Online instructor-paced asynchr.***	***Online instructor-paced synchr.***	***In-person workshop***	***Live webinar***
Lead Drive	2	1 (from 2 options)	1[a]	1[a]	6
Create Embed	2	1-3 (from 3 options)	N/A	1	6
Facilitate Employ	2	N/A	N/A	N/A	6

[a] These learners chose between the synchronous online course and the in-person workshop

C. Learning Strategies and Theoretical Frameworks

Most courses and activities that constitute the learning journeys follow guidelines as recommended by research findings stemming from the Science of Learning field. The self-paced asynchronous material includes frequent low-stake quizzes (ungraded digital knowledge checks) to promote memory retrieval practice and reinforce learner comprehension and learning retention about the content covered [12, 13]. The length of the readings and videos is set to align with the learner's attention span. The live webinars are designed to reiterate concepts and content, promoting retrieval practice and reinforcing consolidation [14]. The instructor-paced asynchronous courses use spaced and/or interleaved learning practices [15], present learners with pre-completed (a.k.a. worked) and faded examples [16], and include formative and summative assessment [17,18]. Moreover, peer-to-peer learning was encouraged using facilitated online forums [19]. The online instructor-paced synchronous course focused on team-based and experiential learning, hands-on activities and case studies [20]. It was also scaffolded to facilitate live interactions between peers and to promote group discussion and peer learning [21]. The in-person experiential workshops were guided by a learner-centric pedagogy and focused on hands-on team-based group projects. Workshops were also complemented by introduction of case studies and short demonstrations followed by class discussion [22]. Worked and faded examples were implemented to facilitate learning via real-life, USAF- and DoD-relevant examples (e.g. AI for drone navigation using computer vision) [23, 24].

III. RESEARCH COMPONENT

The overarching research goal of this program is to support and inform future decisions regarding appropriate pedagogy, learning modalities, technological innovations, bespoke content, and platforms that should be combined to guide and advance the design of cutting-edge AI education for diverse learners, at scale.

It is worth mentioning the challenge posed by the overarching research needs driving this educational program: the sheer diversity of the USAF learning base is unique. Overall, it has over 680,000 personnel with an educational background from high school to graduate degree, ages 18-60, and a full spectrum of officer and enlisted ranks that pose different interests, expectations, and needs.

With all these considerations, the following research design and timeline were put in place.

A. *Participant selection*

Air force and DoD personnel were selected to participate in the academic activities and placed in one of the three learning journeys based on their roles at the USAF and DoD. All learners were invited to participate in the research study: Lead-Drive (n=100), Create-Embed (n=30), and Facilitate-Employ (n=100).

B. *Recruitment*

All research activities were approved by MIT (COUHES) and the Air Force (HRPO) IRB offices, and all USAF and DoD personnel received commander approval to be allowed to participate in the program's research component, should they decide to do so.

The research team, with support from the USAF-MIT Artificial Intelligence Accelerator unit (DAF-AIA), invited all learners to the study and provided informed consent via an online platform (Qualtrics). All survey respondents used a unique user ID that allowed anonymity but permitted the research team to connect their responses across surveys.

C. *Research Design and Timeline*

Our research data come from three different instruments and populations: surveys, interviews and "*gap analysis*" reports.

a) Surveys: The research team designed and delivered (via the Qualtrics platform) a pre-questionnaire (baseline assessment), two check-in questionnaires, and a final exit post-questionnaire for all three cohorts of learners. The pre-questionnaire seeked to understand learner demographics and educational level, as well as prior familiarity with AI related content, pedagogies that will be implemented during the program, and educational technology the learners will be asked to use. Furthermore they had to answer questions about their own personal interest in AI. The two check-in questionnaires were sent throughout the learning journey once learners completed specific courses or activities (as seen in Fig. 4). After a number of completed courses and live events, the surveys asked learners to self-report their perception about AI content, the pedagogies and technologies employed, engagement and success regarding learning goals. For courses dropped, participants were inquired on the reasons for dropping out. Additional questions about the program interest, relevance to work, and the learner overall experience were included as well. All learners were presented with the same questionnaires to properly compare responses across learning journeys, USAF and DoD roles and educational backgrounds. By the time this paper is getting prepared data from the pre-questionnaires and the 2 check-in surveys have been collected and analyzed. Currently, the post-questionnaires have been deployed and data is being gathered.

b) Interviews: Future iterations of the program would be enriched by understanding the logistical hurdles the project team had to deal with to make the program possible, especially when thinking about scalability. A subgroup of the project team (n=5), that directly interfaced with learners to provide technical and logistical support, is currently participating in 30-minutes interviews. The goal of these interviews is to further understand various factors that may have worked as facilitators or challenges during program setup and implementation. The topics covered include technical and logistical challenges, facilitating factors, actions taken and improvement recommendations.

c) Gap analysis: For this first implementation round of the program MIT was provided with predefined learner profiles, as well as with desired learning objectives, skills, and competencies set by the DoD. These set guidelines were used to structure the three learning journeys using mainly off-the-shelf courses from the extensive MIT AI catalog, with the addition of some customized experimental courses. Looking into the future of the program, MIT AI experts were invited to perform a gap analysis of the learning profiles, their designated skills and the MIT-proposed learning journeys. AI experts were also asked about the specific content included in each course. The goal of the gap analysis is for AI experts to highlight necessary, missing or redundant content, as well as suggest changes to the learner profiles and/or expected skills around AI, and better map the learning journeys to the MIT AI catalog.

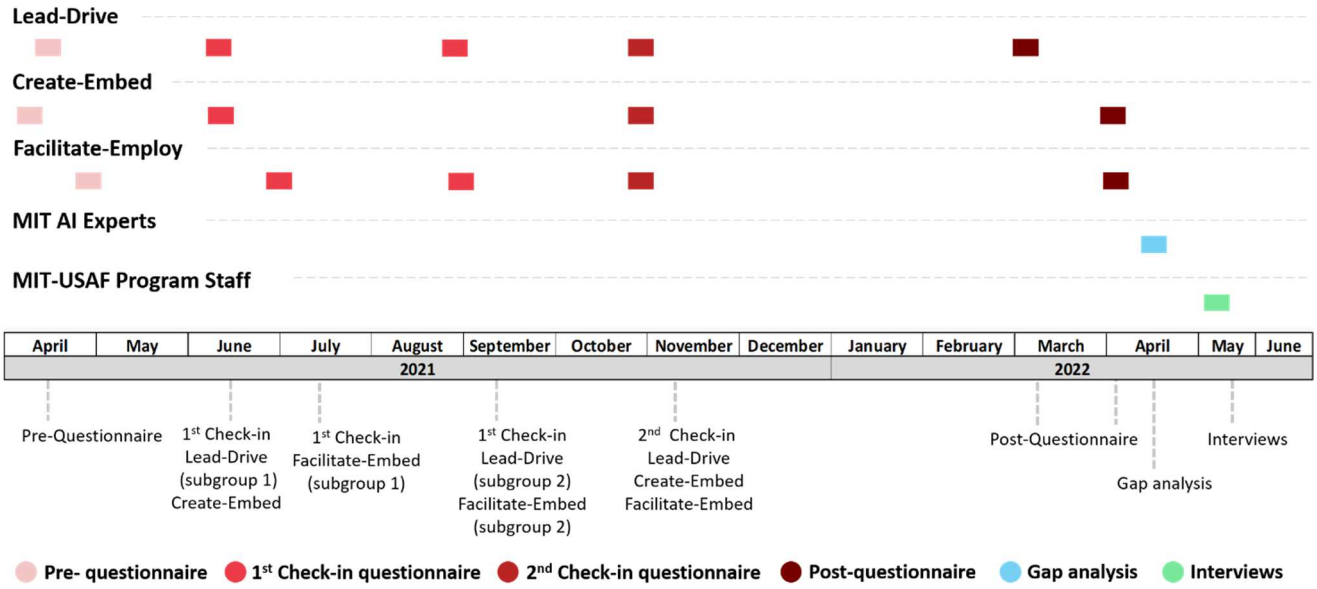

Fig. 4. Research data collection timeline from learners, MIT-USAF staff and MIT AI experts

To complete this task, 9 MIT and USAF AI experts were selected and gap analysis guidelines and rubrics for evaluation were provided to them in January 2022. The MIT AI experts are currently into the process of providing their assessment reports to the project team.

Fig. 4 presents a summary of the research timeline for data collected from the learners, program staff and MIT AI experts

IV. Research Findings and Future Recommendations

Academic activities for the Lead-Drive cohort were completed on February 7th, 2022. Academic activities for the Create-Embed and Facilitate-Employ cohorts will be completed on April 15th, 2022. The research team invited participants to fill out the final exit post-questionnaire only after learners finalized all courses and activities. For that reason, the following preliminary findings only cover up to the second check-in questionnaires. Results from the interviews and gap analysis will be shared in future publications.

The initial data analysis focused on survey participation, content difficulty, the time needed to complete the courses, comfort level regarding the employed pedagogies, the usability of educational technology, interest towards content, relevance with current work in USAF and DoD, as well as learner recommendations for improvement.

A. Survey participation

We noticed that learner participation in the study was decreasing with time, as they were progressing in their learning journeys. Also, a small number of participants accepted to complete surveys and provide feedback to the team but chose not to consent to have their data used for research purposes, but only to be used as internal feedback that would help improve future iterations of the program. Table III presents the percentage of participation in all surveys, tapering down from the pre-questionnaire to the second check-in (for all learning journeys). Findings have been presented and future recommendations have been provided with these sample-size restrictions in mind.

TABLE III. Percentage of Survey Participation per Cohort

Cohort	**Percentage of participation in all surveys**		
	Pre-questionnaire	***First check-in***	***Second check-in***
Lead Drive (n=100)	73%	25%	15%
Create Embed (n=30)	96.7%	36.7%	30%
Facilitate Employ (n=100)	63%	14%	6%
All cohorts (n=230)	71.7%	21.7%	30%

B. Learning Journey completion

Given that access to the courses and activities in each learning journey required multiple delivery platforms, and progress data was not shared across these, the program team implemented in the AI portal a completion self-reporting tool. It required learners to acknowledge completion of the activities, courses and events (mandatory and optional) by checking boxes. Learners that self-reported completion of 90% or more of the mandatory content, and passed their instructor-led courses, received a certificate of completion at the end of the program. Program certificates were granted to 78%, 76% and 63% of the Lead-Drive, Created-Embed and Facilitate-Employ learners respectively [5]. Moreover, if we add the number of learning minutes (content self-reported as completed) covered by all learners we get 957,000 minutes (15,950 hours), reflecting an important level of engagement in the program activities within the organization.

C. Pedagogy

The Lead-Drive cohort responded very positively to a team-based and hands-on based learning experience that complements more traditional learning formats consisting of lecture and group discussion. Members of this cohort have also expressed interest towards more professional/soft skills.

Regarding the Facilitate-Employ cohort, learners responded rather negatively to the lack of live communication with course instructors and the absence of a community of learning. Specifically, some learners suggested the inclusion of live Q&A sessions with AI experts and opportunities to interact with their peers.

Furthermore, based on recommendations from learning experts, in all learning journeys, the self-paced asynchronous material could benefit from inclusion of clear learning objectives and a more strategic placement of the low-stake quizzes (knowledge checks).

D. AI Content and Curriculum

The Lead-Drive cohort requested more content on AI and organizational change and practical skills associated with how to bring AI into their organization or make it relevant to their current work. Learners mostly found the content interesting, but some indicated they could not see a direct application to their work.

Additional feedback coming from some Create-Embed (i.e. software developers) learners included that they needed more time to complete the courses, and many did not feel adequately prepared to follow some of the math-intensive content.

Overall, learners from all cohorts requested to see more case studies and application examples with relevance to the USAF and DoD.

E. Technology to Support Learner Experience

There are several improvements to the tools and technologies to deliver the learning experience at scale. All learning journeys were presented via a unified portal (AI portal). Learners mentioned this portal needs improvement from the usability and user experience point of view. Learners would like portal features added to support interaction with experts as well as the ability to ask questions and interact with other learners as they go through the material.

Furthermore, many learners mentioned the content was not accessible at work due to the USAF and DoD firewall blocking the AI portal on their designated computers. These issues changed the expected learning regiment: it was initially proposed for learners to go over the material during working hours. These accessibility issues made it only possible for most learners to cover material during their personal time, affecting course compliance and engagement.

F. Modalities, Engagement & Learning

From preliminary analysis of the courses and activities there are additional best-practices coming from the Science of Learning, as recommended by MIT learning experts, that could be introduced in the learning journeys and possibly improving the learner experience. These would inform how to do assessments and low-stake quizzes more effectively, rethink the sequencing of curriculum and content to better implement spaced and interleaved learning, introduce new appropriate case studies and worked examples throughout courses, and create an active community of peers to facilitate and promote peer-to-peer learning and programmatic engagement. These additions will especially benefit learning through the self-paced asynchronous activities, which will further support program scalability.

V. Future work: From Research to Practice

Research findings and the overall learner feedback provided input used to redesign a future iteration of the AI educational program. These future learning journeys are expected to better answer the educational needs of such a diverse body of learners, at scale, by incorporating and implementing more best practices informed by the Science of Learning. Moreover, as future learners will possibly go through the next version of this program, optimally a comparative multi-cohort analysis of the learner experience will allow for a more systematic analysis (regarding pedagogy, content and technology) of the impacts of adding and changing different features and materials.

A. Redefined Learning Journeys

Learning journeys are currently getting redesigned for the Lead-Drive and Facilitate-Employ archetypes. The cohort size and starting dates for these new learning journeys are still to be defined. The upcoming cohorts will experience content redefined by the following key principles (driven by the research findings): active learning, authentic challenge-based learning, retrieval practice, spaced and interleaved learning practice, and presentation of worked-and-faded examples. In greater detail these principles are mapped to content and structure changes by:

- Restructuring the learning objectives in the self-paced asynchronous courses to better align with desired content and skills development and retention.
- Enhancing learning retention by adding appropriately designed and appropriately placed low-stake quizzes in the self-paced asynchronous courses to help learners engage in retrieval practice and spaced and interleaved practice.
- Implementing active learning by adding new tools to support live Q&A events with AI experts, and learner cognitive engagement through peer discussion and peer-learning. Also, by enhancing the curriculum with USAF and DoD relevant examples and case studies.
- Modifying and augmenting activities and the structure of the online instructor-paced synchronous experiential course to better reflect active challenge-based learning principles and introduce new AI content and skills through the worked-and-faded examples paradigm. Also, by adding more USAF and DoD-specific activities.
- Further enhancing active learning and challenge-based learning in the Lead-Drive learning journey by possibly adding an AI Innovation Bootcamp component (a new additional pedagogical approach for professional skills training) to address specific USAF- and DoD-relevant professional skills, AI mindset development and organizational change.
- Adding new technology to further support the development of communities of learning.

B. Research Approach

These revised learning journeys arise multiple questions regarding the learner efficacy, engagement and experience, and how those can be explored in diverse learners, at scale. Some of the topics to possibly explored in the future include assessing and evaluating:

- Team-based learning and how to do it effectively and at scale.
- The effect of complementing the original team-based and hands-on based learning with the bootcamp-style pedagogical model (for the Lead-Drive cohort).
- The impact of structuring communities of learning and incorporating live sessions with experts.
- Proper iteration and design to promote shorter learning journeys, especially in consideration of the time commitment of USAF and DoD learners who are also active with their day jobs.
- Direct relevance and practical impact of the learning journey to the learner's job and organization.
- The tradeoffs between in-person versus online learning and how to bring the best of both to learning at scale.
- The impact of improvements to the AI platform, including data analytics, to better support the learner experience.
- How learning engagement and efficacy can be maintained across a larger scale of learners, as these numbers might reach the thousands.

VI. Conclusions

AI literacy and AI technological adoption are fundamental to adequately navigate the continuous changes brought by technology to the world, the way we live, study and work. Proper training in AI skills, concepts and mindsets require carefully designed educational programs following pedagogies, methods and technologies that respond to the learners background, available resources and learning needs and expectations. Nevertheless, AI educational programs are at a nascent state and are usually focused on a specific niche,

namely highly technical professionals with computer science and math background. Democratization of AI and AI education require a deep understanding of optimum ways to offer AI training, online and in-person, to learners with diverse professional roles and with different educational backgrounds. The proposed AI educational program is a first step into bringing AI training to diverse learners, in a scalable way.

Research findings suggest three major content and curriculum enhancements that will be addressed in future iterations of the program to more effectively meet the desired learning outcomes. These enhancements include adapting to follow more best practices informed by the Science of Learning into the self-paced asynchronous material; providing participants with more opportunities for learning community engagement and support, and participation in live events, especially those following learning journeys that lack in-person activities; and adding additional case studies that are work-relevant.

Through these improvements a possible comparative multi-cohort experimental design can allow a better understanding of the features that provide the best learning experience and, ultimately, guide the design of future AI training programs suitable to all members of society.

ACKNOWLEDGMENT

Research was sponsored by the United States Air Force Research Laboratory and the United States Air Force Artificial Intelligence Accelerator and was accomplished under Cooperative Agreement Number FA8750-19-2-1000. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the United States Air Force or the U.S. Government. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation herein.

REFERENCES

[1] J. Bughin, E. Hazan, S. Ramaswamy, M. Chui, T. Allas, P. Dahlström, N. Henke, and M. Trench. "Artificial Intelligence. The next digital frontier?," McKinsey Global Institute report, June 2017. Available on Apr. 2022 from https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/how-artificial-intelligence-can-deliver-real-value-to-companies

[2] L. Halpin, and D. Dannemiller. "Artificial intelligence. The next frontier for investment management firms," Deloitte report, 2019. Available on Apr. 2022 from https://www2.deloitte.com/global/en/pages/financial-services/articles/ai-next-frontier-in-investment-management.html

[3] C. Cath. "Governing artificial intelligence: ethical, legal and technical opportunities and challenges," Phil.Trans. R. Soc. A. 376: 20180080, 2018. http://dx.doi.org/10.1098/rsta.2018.0080

[4] US Department of Defense. "Summary of the 2018 Depart. of Defense Artificial Intelligence Strategy," 2018. Available on Apr. 2022 from https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF

[5] US National Defense Authorization Act for Fiscal Year 2020. Public Law 116-92, 116th Congr. 2020, page 133 STAT. 1198. Available on Apr. 2022 from https://www.govinfo.gov/content/pkg/PLAW-116publ92/html/PLAW-116publ92.htm

[6] US DoD Joint AI Center (JAIC), DoD Chief Information Officer. "Department of Defense Artificial Intelligence Education Strategy," 2020. Available on Apr. from https://www.ai.mil/docs/2020_DoD_AI_Training_and_Education_Strategy_and_Infographic_10_27_20.pdf

[7] A. Eguchi, H. Okada, Y. Muto. "Contextualizing AI education for K-12 students to enhance their learning of AI literacy through culturally responsive approaches," KI - Künstliche Intelligenz, 2021, 35:153–161. https://doi.org/10.1007/s13218-021-00737-3

[8] I. Lee, S. Ali, H. Zhang, D. DiPaola, C. Breazeal. "Developing middle school students' AI literacy," SIGCSE '21: Proc. 52nd ACM Tech. Symp. on Comp. Sc. Ed., March 2021: 191-197. https://doi.org/10.1145/3408877.3432513

[9] T. K. F. Chiu. "A holistic approach to the design of artificial intelligence (AI) education for K-12 schools," TechTrends, 2021, 65:796–807. https://doi.org/10.1007/s11528-021-00637-1

[10] H-T. Liao, Z. Wang, X. Wu. "Developing a minimum viable product for big data and AI education: action research based on a two-year reform of an undergraduate program of internet and new media." ICBDC'19: Proc. 4th Intern. Conf. on Big Data and Computing, May 2019: 42-47. https://doi.org/10.1145/3335484.3335509

[11] A. Bagiati, A.F. Salazar-Gomez, J. Radovan, K. D. Kennedy, and C. Breazeal. "Learning journeys for scalable AI education: an MIT-USAF collaboration," Proc. 50th Conf. of the Europ. Soc. for Eng. Ed. (SEFI), September 2022, in press.

[12] K. Davis. "Improving motivation and knowledge retention with repeatable low stakes quizzing," Proc. ASEE 2009 Annual Conf. & Exposition. Austin, Texas, 2009, 10.18260/1-2-5436

[13] K. L. Kenney, and H. Bailey. "Low-stakes quizzes improve learning and reduce overconfidence in college students," J. Scholarship of Teach. and Learning, 21 (2), 2021. https://doi.org/10.14434/josotl.v21i2.28650

[14] J. D. Karpicke, and H. L. Roediger. "Repeated retrieval during learning is the key to long-term retention," J. Memory and Language, 57 (2), 2007: 151-162. https://doi.org/10.1016/j.jml.2006.09.004.

[15] H. L. Roediger, and M. A. Pyc."Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice," J. Applied Research in Memory and Cognition, 1 (4), 2012: 242–248.

[16] A. Renkl. "Learning from worked examples: How to prepare students for meaningful problem solving," in Applying science of learning in education: Infusing psychological science into the curriculum, V. A. Benassi, C. E. Overson, and C. M. Hakala, Eds. 2014: 118–130.

[17] I. Rolfe, and J. McPherson. "Formative assessment: how am I doing?," The Lancet, 345 (8953), 1995: 837-839. https://doi.org/10.1016/S0140-6736(95)92968-1.

[18] D. D. Dixson, and F. C. Worrell. "Formative and summative assessment in the classroom," Theory Into Practice, 55 (2), 2016: 153-159. https://doi.org/10.1080/00405841.2016.1148989.

[19] J. McLuckie, and K. J. Topping. "Transferable skills for online peer learning," Assessment & Eval. in Higher Ed., 29 (5), 2004: 563-584. https://doi.org/10.1080/02602930410001689144

[20] K. M. Bonney. "Case study teaching method improves student performance and perceptions of learning gains," J. Microbiology & Biology Ed., 16 (1), 2015: 21–28. https://doi.org/10.1128/jmbe.v16i1.846

[21] J. A. Schell, and A. C. Butler. "Insights from the Science of Learning can inform evidence-based implementation of peer instruction," Front. Educ. 3 (33), 2018. doi: 10.3389/feduc.2018.00033

[22] Y. Kong. "The role of experiential learning on students' motivation and classroom engagement," Front. Psychol., 12 (771272), 2021. https://doi.org/10.3389/fpsyg.2021.771272

[23] E. Retnowati. "Faded-example as a tool to acquire and automate mathematics knowledge," J. Physics: Conf. Series. 824 (012054), 2017. http://dx.doi.org/10.1088/1742-6596/824/1/012054

[24] T. L. Hesser, and J. L. Gregory. "Exploring the use of faded worked examples as a problem solving, approach for underprepared students," Higher Ed. Studies, 5 (6), 2015. http://dx.doi.org/10.5539/hes.v5n6p36