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TA TO AI: TINKERING APPROACH TO ARTIFICIAL INTELLIGENCE AND COMPUTATIONAL THINKING EDUCATION IN INDIAN SCHOOLS

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INTRODUCTION

COMPUTATIONAL THINKING AND ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is playing significant roles in our present and will contribute to our future endeavors; hence, there is a need to educate people about it. In his 2020 CTE keynote, Hal Abelson talked about technical skills, social skills, and ethical judgment as essential abilities for understanding and working with AI. Today's computational thinking education (CTE) lacks exposure to skills like statistical methods for data perception and representation; reasoning with creativity and an understanding of models of learning; and natural interactions for developing broad perspectives on social impact, all of which are at the core of AI. A need for developing national guidelines and resource directories for AI education in K–12 has been expressed at many CTE forums.

Computer education in Indian schools has evolved opportunities for developing a lot of projects and applications with computational thinking at its core. Such needs for specialized experience-based education in India have been addressed under the Atal Innovation Mission (AIM) (Atal Innovation Mission, 2020) of NITI Aayog, Govt. of India, through the Atal Tinkering Lab (ATL) initiative. Computational thinking has been developed as an independent module for the ATLs. Further, India's need for AI education is being addressed at both the state and central government levels. AIM's ATLs in collaboration with the National Association of Software and Service Companies (NASSCOM 2016) have developed a set of AI modules. The ATLs are state-of-the-art learning spaces that serve as a platform for children to explore, play, build, and experience concepts like AI with these modules, which are in line with the National Education Policy 2020 (MoE 2020) released by the Ministry of Education, government of India.

The diffusion of AI has enabled a wide range of activities. UN activities on AI report (Truby 2020) the use of machine learning (ML) techniques for environmental protection, disaster preparedness, and the development of cloud-based geospatial solutions for enhanced natural resources management. The proliferation of predictive algorithms and natural language processing has transformed business processes, including fraud detection, processing insurance claims, and customer interactions. AI's predictive capabilities are reducing costs and altering organizational structures. Networked turbines, intelligent power distribution, and automated manufacturing rely on AI technologies (Agrawal, Gans, and Goldfarb 2018).

The structural changes driven by technologies such as AI have both economic and social implications. The automation of tasks may result in labor displacement, which may need reskilling/ upskilling for reappointment. The existing AI applications may not have the potential to replace all tasks conducted by labor in masses but only those tasks that are routine and noncognitive (Macias-Fernandez and Bisello 2020). It has been estimated that by 2030, the global market in AI is likely to be in the range of 15–15.5 trillion dollars out of which India's share will be close to a trillion (Chen et al. 2016). The next generation of young Indians will want to challenge the "status quo," and there's no gainsaying; they may not remain content even with a trillion-dollar share. They will be limited only by the magnitude of their aspiration.

Apart from increasing the budget allocation for AI, India's government has plans to improve skills in the area of artificial intelligence, big data, and robotics. There was an absolute need to revise the education curriculum, not just for technology institutes but also at schools, to include AI. Moreover, AI needs to be understood as it is socially embedded, interacting with and affecting individuals and communities in myriad ways.

Therefore, AI training should go beyond technology curricula to include social sciences to understand the impacts of AI and contribute to the process of constructing AI algorithms and their assessment. Given its impact, there was a need to introduce AI to students early on to relate to it and associate with its implications to build their foundations over time. To achieve this goal, the following objectives were set:

- Create a fit-for-purpose technology and tinkering-enabled learning and experimentation platform for students to explore various AI dimensions.
- Equip the labs and learning facilitators with necessary tools and learning support to develop student skills, knowledge, and competence in AI. Support will include a holistic curriculum, content, AI DIY Projects (Soft), and so on.

These objectives were addressed by introducing the AI modules in ATLs, a setting that is built to encourage learning and problem-solving by tinkering.

TINKERING AS A VEHICLE TO EXPERIENTIAL LEARNING

Exploration and playful experimentation (play) have been the basis of gaining new knowledge and learning new skills (Resnick and Robinson 2017). In a constructionist approach to learning, building solutions by situating the problem-solving process in an authentic scenario enhances the learning experience (Bransford, Brown, and Cocking 2000). Tinkering is one such practice that includes artefact creation with problem-solving. It has been considered a novice and expert practice that sets it apart from most classroom practices (Danielak, Gupta, and Elby 2014). It does not make tinkering better or worse, but it does make it an authentic professional practice (Berland et al. 2016). Tinkering provides the opportunity to work in a real-time environment with immediate feedback on actions taken, making it a potential means for developing skills by applying and testing one's understanding of concepts. We believe that tinkering with digital platforms and electronic components provides opportunities for exploring concepts and evaluation by applying the AI's concepts to solve problems. Such an explorative hands-on approach supports the development of cognitive and affective skills that support the learning with exploration in higher-education students (Brennan and Resnick 2012). Furthermore, such applied practices have been known to develop motivation and confidence in using newly learned knowledge by overcoming the initial inhibitions and fear of something new.

THE INDIAN TINKERING INITIATIVE FOR K–12: ATAL TINKERING LABS

The Atal Innovation Mission (AIM), housed at NITI Aayog, government of India, sets up state-of-the-art maker-spaces—the ATLs, in schools across the country for adolescent students in sixth to twelfth grade. Children as young as twelve years of age are being introduced to the world of cutting-edge technology with ATL in schools. ATL is the flagship initiative to foster curiosity and encourage students and teachers to experiment, explore, and follow their learning path. It is done by empowering them to think differently about problems and develop innovative solutions by leveraging the latest technology tools including 3D printing, Internet of Things (IoT), robotics, miniaturized electronics, space technology, drone technology, and technology-inspired textiles, and now adding AI to the list. At ATL, students empathize, ideate, design, and prototype using twenty-first-century technologies such as IoT kits, smart electronics, rapid prototyping technologies, 3D printing, and other DIY kits. This has allowed these youngsters to test their ideas and use them to address the grassroots challenges within their local communities. The ATL program's unique pedagogy approach is centered around hands-on learning and making skills (AIM 2020).

Under the ATL scheme, grants-in-aid are provided to schools selected after fulfilling specific requirements of space and workforce and adhering to certain conditions. The aid is for setting up the ATL, which is to be used within a maximum period of five years, including operational and maintenance expenses. As of December 2020, 14,916 schools have been selected to establish ATLs, and approximately 6,500 ATLs have been sanctioned, covering more than 90 percent of India's districts (ATL Schools 2020). These labs have been established in both public and private schools. The majority of them are in coeducational and girls' schools, which are also serving as community hubs of innovation, providing a platform to transform how the youth of the community learns, thinks, ideates, and innovates (NITI Aayog 2018).

To further nurture the school students, the Mentor of Change (MoC) program, a citizen-led national movement, was launched by AIM. Skilled professionals provide pro bono mentoring to young ATL innovators (Atal Innovation Mission 2020). ATL also provides to other sections of the community—including parents, mentors, and other individuals—an opportunity to give life to their ideas. Through frequent community sessions, ATL aims to shape an ecosystem wherein every individual can find solutions to day-to-day personal problems or the society and the country. Such initiatives enhance ATLs' ability and make them ideal for a tinkering-based approach to learning.

ARTIFICIAL INTELLIGENCE MODULES FOR ATL: THE JOURNEY

With ATLs' potential to expose learners to AI, the subject matter expertise was brought in by NASSCOM. It was mutually decided to deliver the AI module in two phases: the AI base module and then the AI step-up module, as the extension of the base module. The initiative's core philosophy was to "trust the learners with their learning path and scaffold them to stand when they fall." The first and most crucial step of the more extensive process was comprehending and understanding the present scenario and expectations of the learners, teachers, and mentors at the school. Many interactions were conducted with school students in the ATLs, their teachers, and mentor communities across the country. Additionally, various models content released or currently deployed across various ATLs were surveyed.

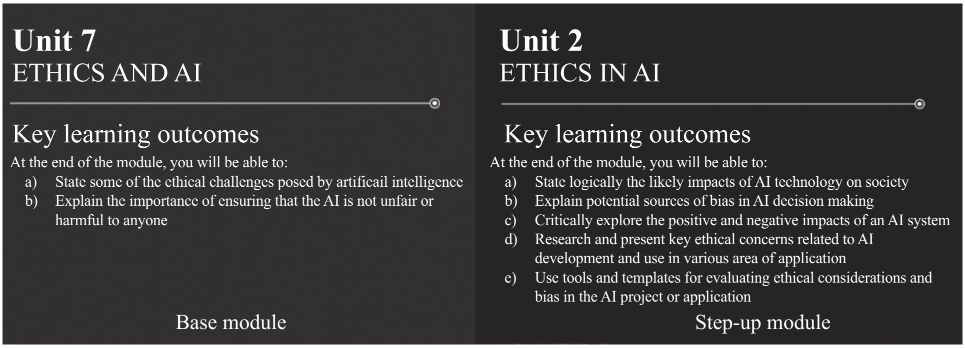
A workgroup from industry and academia was formed to bring in the knowledge, expertise, and experience. The majority of the workgroup constituted tech companies and startups building ed-tech products and services industries using these products. The representatives were practitioners, technology integrators, and educators of AI from organizations like Accenture, Adobe, Amazon, Arm, Bosch, GE, India AI, Microbit, Microsoft, Nvidia, Progilence, SAP, Stempedia, Stemrobo, TechM, Tevatron Tech, Unity, and WIPRO. They contributed by setting expectations, sharing resources, and building activities that were closer to the real-world implementation of AI. The other members of the workgroup were from academia with research experience in technology-enhanced learning, learning environments, and use of educational technology tools and strategies represented by the Interdisciplinary Programme in Ed Tech of the Indian Institute of Technology Bombay. They contributed to the structuring of modules as activity books with an underlying pedagogy based on tinkering. NASSCOM and members from AIM coordinated the activities of the entire workgroup. Group interactions every fortnight gave structure and direction for developing, implementing, and refining the modules. Smaller specialized workgroups contributed to a specific set of outcomes like specific chapters, relevant activities, and examples. The entire content was divided into two modules, the basic and step-up modules. It took around four months each for the base module and the step-up module. NASSCOM hired Progilence to coordinate ground research and to mediate the industry and academia consultation and contributions. They also ensured the alignment of the philosophy, the pedagogical recommendations, learner expectations, and academic curriculum. They were instrumental in instructional design and in publishing, reviewing, and updating the modules.

Based on the ground survey and interactions between the workgroup members, it was realized: (1) the already available content for learning AI is domain- and platform-specific and lacks open exploration, (2) the approach of the available content lacks the opportunities for learning with real-life implementation, and (3) the alignment between the activities of the available learning material with the resources available in the Atal tinkering labs was missing. These aspects were realized to be crucial for an AI learning resource based on tinkering as they help students to apply and evaluate their understanding and expand their exposure to use the concepts in various domains. Moreover, it encourages and engages learners in experiencing AI with activities possible in the spirit of a tinkering lab. Lack of such opportunities could deprive the students from developing an independent capability of working with AI.

To overcome these challenges, it was decided that the modules were to be developed on the basis of progressive formalization, situated in real-life context, argued with analogical scenarios, encourage play by adhering to the norms of tinkering (Resnick and Robinson 2017) and provide scaffolded learning. (These philosophies are discussed in detail in the next section. An overview of their implementation is discussed in the next paragraph, and individual detailed examples have been provided in the next section). As these modules were being developed for a tinker lab, one key aspect driving the design was *tinkerability*, which is ensuring that the learning environment has been designed and set up in such a way that it supports and to some extent encourages the learners to tinker. This can be achieved by incorporating open exploration, fluid experimentation, and immediate feedback (Resnick and Robinson 2017). Fluid experimentation and immediate feedback were achieved by making content interactive with activities, experiments, and simulation platforms guided and encouraged by videos that enable students to work through and learn the various concepts of AI. Open exploration was ensured with activities having a low floor (easy and simple to start without prior knowledge), high ceiling (allows highly complex activities and tasks that require expertise), and wide walls (provides several options to choose from to do the same kind of tasks). A number of platforms were recommended that allowed learners to choose the expertise and challenges they would want to take and guide their learning. The complexity was gradually increased within the chapters of the modules and among the modules. The step-up module built on the concepts and the problems of the base module.

To provide an overview of the flow of a concept in and across the modules, let's look at an example. Let us see how ethics in AI was designed and implemented in the base and step-up module. First, adhering to the progressive formalization, the learning content was broken down into two chapters, unit 7: Ethics on AI in the base module (Link: https://aim.gov.in/Lets_learn_AI_Base_Module.pdf#page177) and unit 2 of the step-up module (Link: https://aim.gov.in/Lets_learn_AI_StepUp_Module.pdf#page=69). The chapter in the first module provides scenarios, asking learners to take a stance with a motive to kindle their thought whereas in the second module the chapter now formally introduces the impact of technology, talking about types of bias and the sources of that bias, with activities and examples as seen in the key learning outcomes shown in figure 12.1.

Now let's look at how the flow introduces the topic of bias in training data in the first module and then extends it to the concept of fairness in



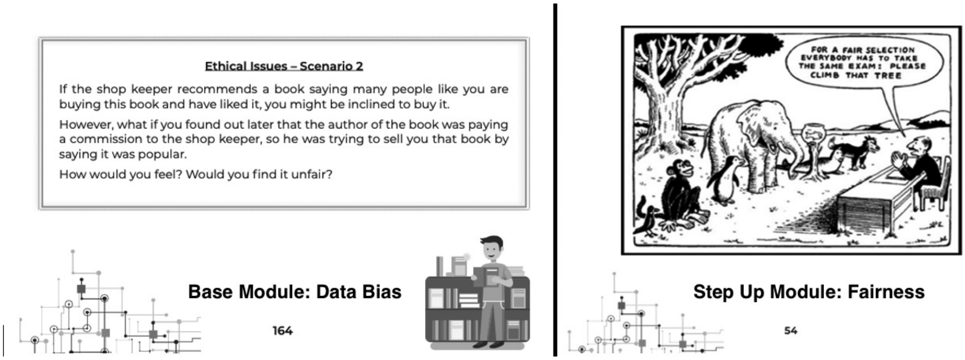
12.1 Progressive formalization: the variations in the key learning outcomes of the two units on ethics in AI.

the second module. This again is an example of progressive formalization at the topic level. The second scenario in ethical issues of the base module (p. 164) as shown on the left of figure 12.2, puts a student in a real-life situation where they are to realize how their choices of books could have been governed by the corrupt dealing of a shop keeper.

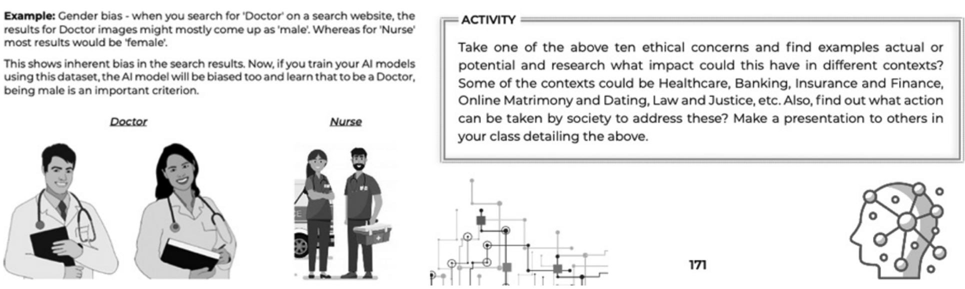
In this case, the learner's empathy helps them relate to a biased recommender system. The step-up module in unit 2 on ethics extends the example of bias to the concept of fairness with more examples, seen in the right side of figure 12.2. Such an approach is also an example of using analogical scenarios situated in a real-life context, which have been extensively used to design the units for ethics in AI. These scenarios where the learners are to take a stand are set as real-life situations to which the learners could relate. To allow learners to experience bias for themselves, the modules further recommend activities like searching for images of doctors and nurses to see the prevalent gender bias of a search engine and then ask them to tinker with search keywords to discover similar bias in various other domains as seen in figure 12.3.

After the activity for gender bias, there is allowance for discussion, and additional activities have been scaffolded with examples in links and videos to enable the learners to explore the topic further. The flow of topics within the module and between the modules is governed by the philosophies to ensure learner engagement with the content.

The base module was specifically devised considering students as young as twelve years of age, with absolutely no prior background in AI.



12.2 Analogical scenarios situated in contexts relatable to real life.



12.3 Activities for learners to discover data bias in AI systems.

The objective was to encourage young students' involvement across the country from both rural and urban areas, promoting inclusive learning in all genders. The base module has seven units. Each unit starts with key learning goals and discusses various concepts with examples and various hands-on activities. Each unit also has additional resources for learners to explore based on their interest and a summary of learning from each unit. For easy access, links are provided along with barcodes to be scanned if using a mobile device or tablet. The step-up module provides a medium for learners to expand their knowledge and experiment with their understanding after becoming familiar with the basics of the AI. The module's design allows learners to explore the field on their own at their own pace with these AI modules; hence, a hands-on module was formulated to kindle the learners' thoughts to experiment and experience. The step-up module is made up of eight units. The units follow a similar pattern of key learnings in the beginning, provide a list of examples and activities that have evolved from the base module, and summarize the learning at the end of each unit. The activity booklet accompanying the step-up module has four basic projects based on block-based coding platforms and two advanced projects that use real-life data to address (1) a transportation problem based on the spread of Covid-19 and (2) a water scarcity problem using satellite imagery.

In February of 2020 on the eve of National Science Day, the AI base module was launched across the country. The step-up module was launched in August 2020 on the eve of India's Independence Day. The successor to the base module built on its concepts, practices, and problems. Artificial intelligence is the future, and with constant research and innovations being conducted in the field, there is a need for curious young minds to be aware of it.

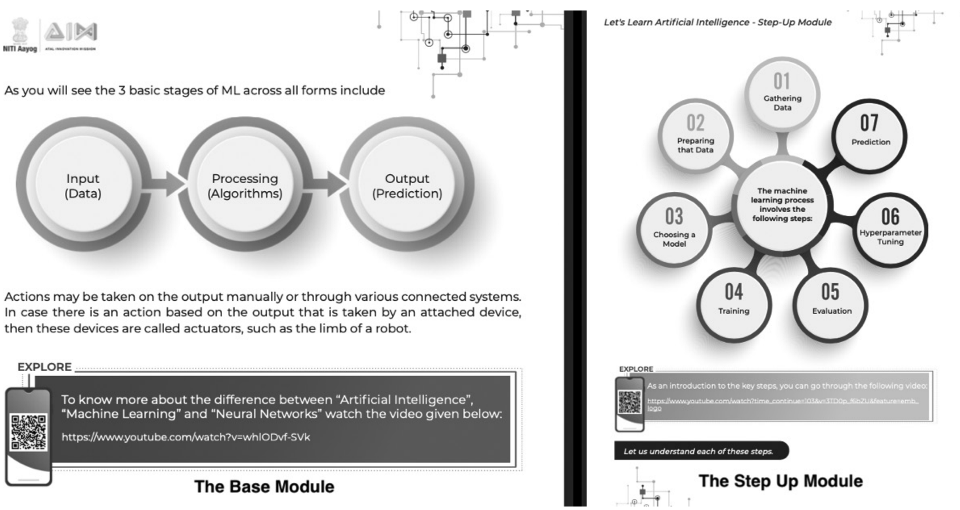
LEARNING AI BY TINKERING

UNDERLYING PHILOSOPHY AND PEDAGOGY

The module's board objective is to trust the learners with their learning path and scaffold them to stand when they fall. To ensure the development of the modules with the stated philosophy, *progressive formalization* was chosen to present the concepts gradually, the activities were *situated in a real-life context*, arguments were provided along with *analogical scenarios*, and activities were designed to encourage *play* with the entire learning experience designed around *tinkering* to solve problems which were *scaffolded* with examples, resources, and mentor interventions. All the theories are briefly discussed along with some examples from certain sections of the modules as follows:

Progressive formalization (Bransford, Brown, and Cocking 2000) requires teaching to be designed to encourage students to build on their informal ideas in a gradual, structured manner that enables them to acquire the concepts and procedures of the discipline. The problems, challenges, and examples from the basic concepts have evolved in complexity in the same or a similar domain when the advanced topics are discussed. This approach aims to motivate and get the learners excited about the subject to start with and then retain the excitement by going deeper using the same problem, creating curiosity by increasing complexity, then later addressing the curiosity by making them do activities as the subject matter advances. Let's take the example of the chapter "Learning," which is unit 2 of the base module, and see how progressive formalization works across the chapter. The chapter starts with talking about how we learn with experiences we gain from our senses and then abstracts that process into how a computer would learn based on data it gets from various sources. To situate the concepts, the chapter uses examples and activities from computer vision and natural language processing (NLP). These activities are simple and allow learners to experience computer vision and NLP by (1) allowing the learner to relate the concepts to something substantial and (2) getting the learners motivated about the content and keep them engaged. Now let's look at how progressive formalization of unit 2 of base module governed the design of the units 3, 4, and 5 of the step-up module. Unit 3 of the step-up module about machine learning takes the concepts of base modules that talk about learning with data and introduces the seven-step formal process of machine learning as seen in figure 12.4.

Further the examples of computer vision and NLP from unit 2 of the base module are now unit 4 and unit 5 of the step-up module. These units discuss ML with domain-specific examples and activities that now allow

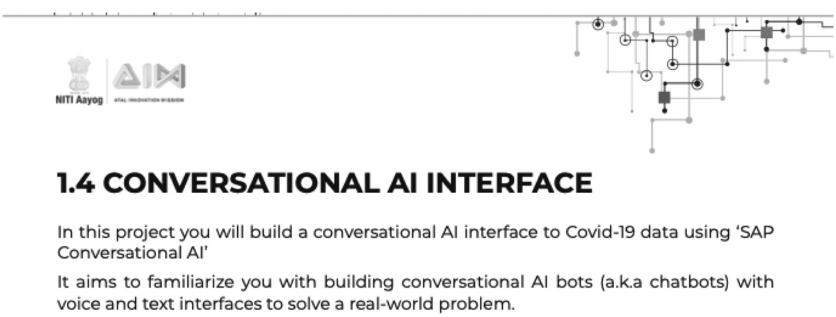


12.4 Formalization of the ML process from the base to step-up module.

learners to build and create the activities they experienced in unit 2 of the base module. In this way, progressive formalization has been designed for concepts along the units they have been discussed in and also in other units across modules.

Learning *situated in a real-life context* (Bransford, Brown, and Cocking 2000) enables a better understanding of abstract concepts by establishing their need in a real-life context using everyday examples. The learners are able to apply and evaluate their understanding with immediate feedback for their actions when based in a real-life context. Activities and projects have been situated in real-life context by providing resources that constitute real-time/real-life data like atmospheric data from open sources and building problems that the learners could relate to. The learners are asked to solve such problems either as thought experiments to get them thinking and/or later by building software- or hardware-based solutions. Activities were designed where the learners are given scenarios and asked about their opinions. Then they challenge their opinions based on conceptual or experiential knowledge. The best example is the projects booklet along with the step-up module. The projects have been divided into basic and advanced. All the projects require the learners to provide real-time data for training ML, and the output is something they can relate to. In the basic set, the conversational interface allows them to build a chatbot that the learners can relate to from the examples and activities of unit 2 of base module and unit 5 of NLP in the step-up module.

The advanced activity 2.1 of the project module includes an image processing project that encourages them to solve a drinking water problem using satellite imagery as seen in figure 12.15. The problem uses real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1.4 CONVERSATIONAL AI INTERFACE

In this project you will build a conversational AI interface to Covid-19 data using 'SAP Conversational AI'

It aims to familiarize you with building conversational AI bots (a.k.a chatbots) with voice and text interfaces to solve a real-world problem.

12.5 Building a conversational interface using AI (chatbot).

satellite images, and the solution to the problem involves finding actual areas covered by waterbodies to compare the coverage with data from a different year. Being able process actual data and do calculations to make an inference about change in surface water coverage impacts the learning of ML and associates it with a substantial outcome.

Analogies have been known to promote learning of the properties of unfamiliar concepts as well as develop new abstractions. Analogy-based scenarios allow the learners to challenge their thought processes to develop argumentation (Gentner and Gentner 1983). Analogical scenarios from multiple perspectives allow learners to associate with challenges that might arise in specific situations, and they have been extensively used to discuss topics like ethics in AI. In both the modules, the chapters on ethics use scenarios as they present some complex situations and then pose questions from multiple perspectives, such as the perspective of the machine, the user, and the programmer. These questions allow the learner to build their ideas and then question them from a different perspective, making them more sensitive about the various challenges associated with AI such as efficiency or ease against privacy and choice. For example, continuing with the example discussed in figure 12.2, the second scenario in the ethical issue of the base module (p. 164): when the learner realizes that his/her choice of books is biased based on a personal interest of the bookkeeper, the learner's empathy from the example scenario helps them relate to a biased recommender system. This example in unit 2 of the step-up module in section 2.2 (p. 53) also discussed in figure 12.3, talks about fairness and shows how biased data could lead to a biased system and have an impact on its users.

Tinkering has been referred to as a playful, experimental, iterative style of engagement in which people are continually reassessing their goals, exploring new paths, and imagining new possibilities (Honey and Kanter 2013). Here *play* has been referred to as experimental play. Play becomes an essential tool for learning in a real-life context as it allows the learners to have a stake in the problem and encourages experimentation with the available resources and one's ideas in the actual problem space with just-in-time feedback that enables reflection (Honey and Kanter 2013). It prepares the learner for real-life scenarios. It also allows one to take multiple perspectives on an action and its impact, which is an essential social skill for developing the mind (Bailey 2002). Tinkering provides a multitude of possible paths taken progressively while situated in a problem space working with immediate feedback. Tinkering as a way of learning focuses on activities built around the concepts that involve using numerous resources to build solutions that allow learners to explore, experiment, and evaluate their understanding of the concepts, in our case in a real-life setting. Tinkering has been known for exploratory learning based on its alignment to several theories of learning. Additionally, the growing availability of design tools has allowed learning through design activities in a constructionist approach (Harel and Papert 1991). Such an approach highlights the importance of young people engaging in learning with the development of external artefacts (Kafai and Resnick 1996) (Roque, Rusk, and Blanton 2013). As discussed previously, learning with tinkering requires the environment and resources to be tinkerable, to support a learners' tinkering ability. Tinkerability was ensured by designing the modules with materials and resources that are known to allow open exploration, fluid experimentation, and immediate feedback. To achieve open exploration, a wide variety of options were made available; for instance, in the activity books, different programming platforms have been provided for the same activity, allowing the learners to choose as per their preference. The same activities could be done on three platforms: ML for kids, Cognimates, and Pictoblox. Various basic activities that start with trying the solutions, like the basic image recognition game in the base module, had been given as an activity of creating similar solutions like building the rock paper scissors game in the project's booklet. Similarly, the basic solutions in the base modules later evolved into complex problems in the step-up module and the activity booklet, which encompass advanced concepts and allow various solution approaches. To support fluid experimentation with quick and easy access to a number of "how to" resources and examples for connecting the activities with concepts have been provided throughout the modules with links and videos available as URLs and barcodes. Immediate feedback has been ensured by using "glass box" platforms and examples that provide the entire solution mechanism, guiding learners to make changes and observe the difference in the changes. Such "glass box" systems allow the learners to observe the impact of the changes they make. Support for tinkering ability was designed into the modules by designing activities for playful experimentation with available AI platforms rather than just giving examples. These activities range from the previously mentioned concept of fairness, discussed with a simple web search activity with the keywords as "doctor" and "nurse" to highlight gender bias, to a more advanced activity of creating and training a system with examples of animals, creating a bias for a specific set. This very example also shows how connections between the concepts of AI and their applications have been designed. Numerous examples that have been listed have evolved as activities with the evolution of the concepts. It was ensured by design that the learners are encouraged to find answers by posing questions and thinking about them. This approach was ensured by providing open-ended problems leaving the learners to figure out the details of the solution scaffolded with questions or examples. The projects book provides the open-ended problem statements in the advanced problem section with links to various resources and an example solution that the students are encouraged to start with and later modify or find a new one based on their understanding.

Scaffolds are like training wheels when one learns to ride a bicycle. As one starts getting the balance right, they are removed (Bransford, Brown, and Cocking 2000). Scaffolds can be technological assistance in the form of digital resources or documents that guide or aid specific processes that may lead to learning, for example, an interactive agent or some design elements of a simulation software. These could be prebuilt or semi-built resources from which the learner could get insights in order to modify them as per their own ideas. Scaffolds could also be in the form of prompts, triggers, or questions from a mentor that aid the learner's thought process. Here, a teacher's role is more of a mentor—one who allows the learners to make decisions on their own, only supporting their thought process and allowing the learners to build their own learning paths. The learners may choose to start by reinventing to gain confidence in the process, which is essential for a learner's motivation and confidence. In today's scenario, the mentor's crucial role is to train the learner to seek information through interaction and investigation rather than provide them with information. The modules have scaffolds in the form of guided activities, quick access links to external resources, and a wide variety of options to choose from. Further, the mentor for change program focuses on training the mentors to guide the learners toward activities for more in-depth exposure to learning. Throughout the modules, the learners go deep into the concepts, but summaries and checks at the end allow them to step back and account for the current topic in the bigger picture of AI.

THE AI MODULES

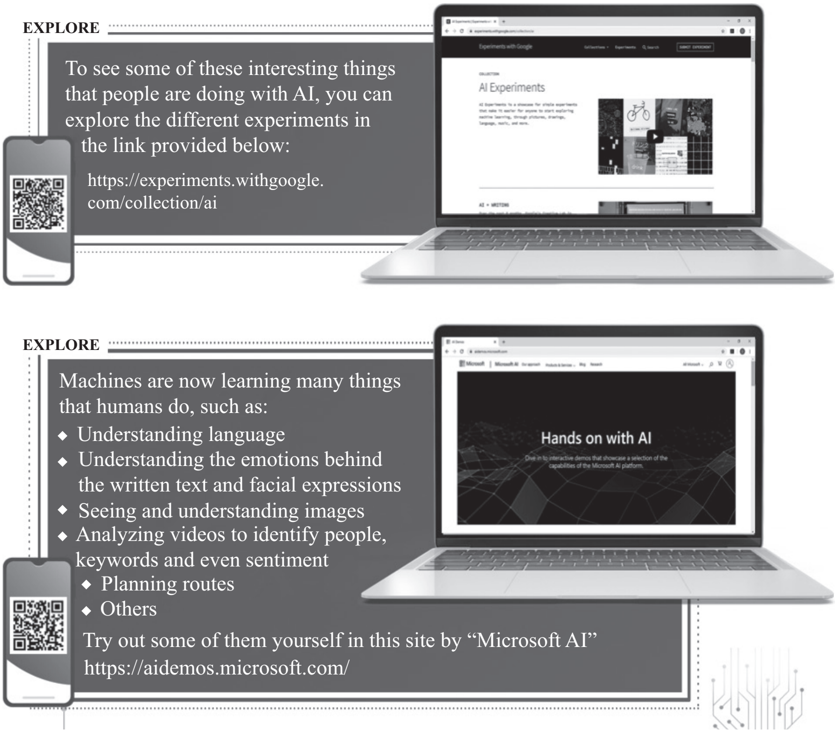
The entire curriculum has been divided into two modules and a project book for hands-on, real-life challenges. The modules are discussed in detail as follows:

Base module The base module's primary objective is to introduce the learners to the basic concepts of AI and allow them to play with the concepts via activities and experiments aided by the inventory of tech available at the ATLs. The module can be accessed at the link https://aim.gov.in/Lets_learn_AI_Base_Module.pdf or using the QR code shown in the figure. The details of the contents in the base module are as follows:

Chapter 1 on introduction to AI aims at exposing the learner to artificial intelligence and its applications to get them thinking about its utility. The chapter introduces the learners to a range of AI applications on the web using various activities, allowing them to tinker with online models. Figure 12.6 shows an example of such resources that have links and QR codes to access the resources. Simulations are a powerful tool for engagement, especially with new concepts.

These activities and their related concepts are additionally scaffolded using videos and reading materials. The idea is to get learners excited about AI and its applications.

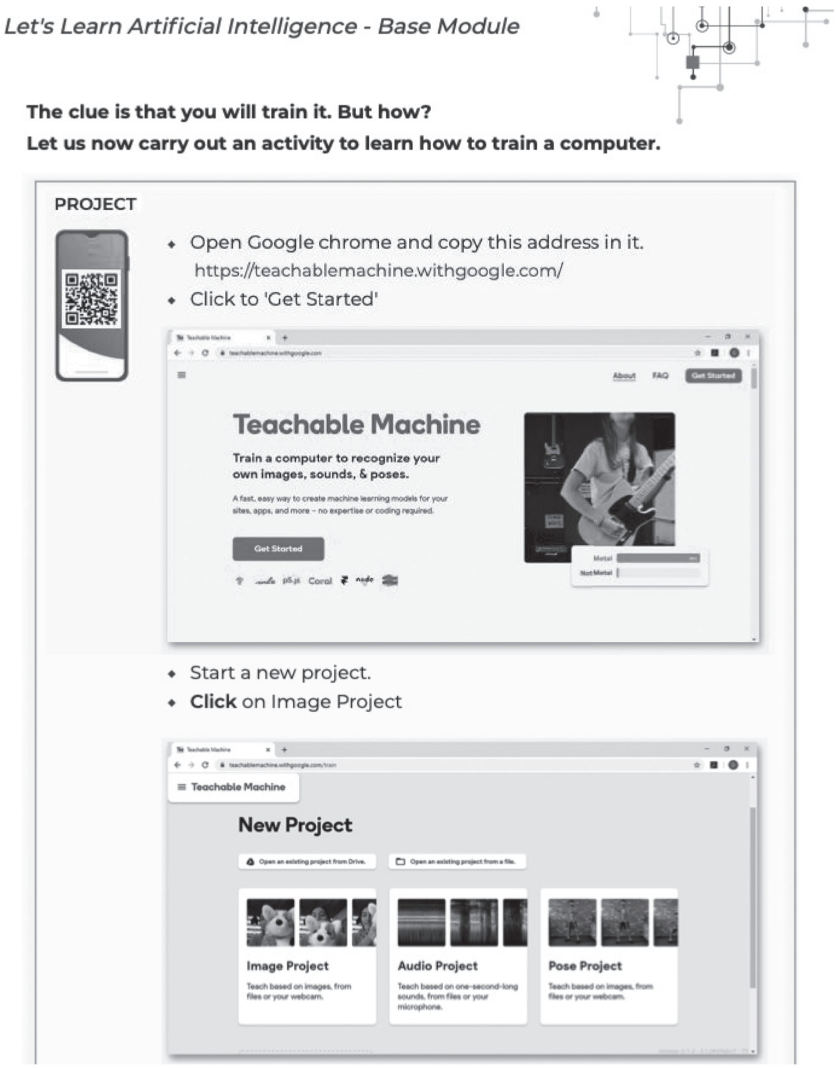
Chapter 2 on learning aims to get the learner to compare and contrast human intelligence and learning within machines. To do so, the chapter uses an online application that introduces machine learning while highlighting its key requirements. Figure 12.7 shows one example of using teachable machines that allow learners to experience how AI can be trained to recognize images. This empowers the learners to experience the training process by doing it on their own. It also introduces students to various ways in which machines learn with respect to human learning



12.6 Actives to explore simulation platforms with quick-access QR codes.

approaches. The examples in this chapter are based on technologies such as speech recognition and computer vision.

Chapter 3 is on data to engage learners with data and data types. Learners do activities to recognize features like centrality. They are provided with different forms of data and try to understand and make simple interpretations from that data. A simple example is shown in figure 12.8 with data in a semiprocessed form from which the learner is to write their interpretations. Learners are exposed to exercises to identify data types as well as ways of capturing data and storing it. The base module has ensured that the learner can differentiate between binary and denary systems and generate binary codes. Scaffolded methods help the learners recognize how binary code systems underpin various data forms like images and sound with applications and examples and exercises.



12.7 Activity that allows the learners to train an AI app to recognize images.

An important takeaway of this chapter highlights the need for data processing capabilities via some simple AI activities.

Chapter 4 on maths and data visualization starts with feature-based classification activity set in a narrative based on likes and dislikes of a pedagogical agent to introduce classification-based AI algorithms. Figure 12.9 shows a stage of a feature selection activity from the narrative of finding the pedagogical agent's favorite shapes. Later, the chapter gets into mathematical

Student Name	Marks in Maths Test
Aarti	YES
Apu	YES
Farah	YES
Anik	MAYBE
Guna	MAYBE
Babu	NO
Devin	NO
Hira	NO
Koel	NO
Total Number of Students: 9	Total YES: 3 Total MAYBE: 2 Total NO: 4

ACTIVITY

What is the information you can extract from this data?

	YELLOW	BLUE	RED	BLACK	GREEN	Total
TRIANGLE	▲	▲	▲	▲		**4**
CIRCLE	●	●	●			**3**
SQUARE	■				■	**2**
Total	**3**	**2**	**2**	**1**	**1**	**9**

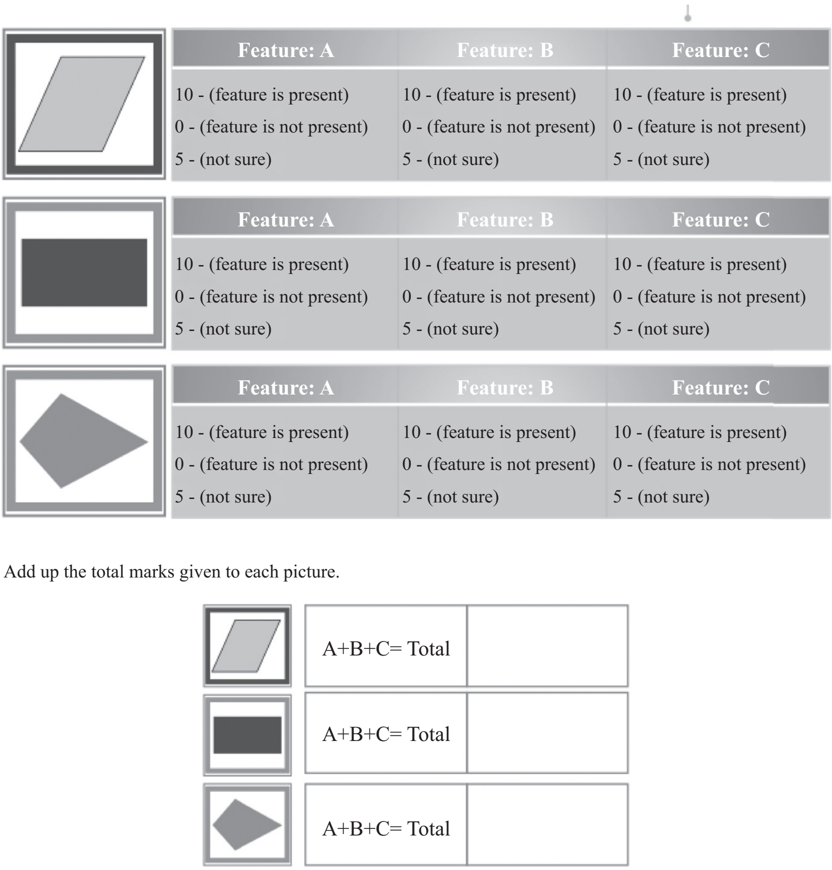
ACTIVITY

What is the information now available from this data?

12.8 Activity for data interpretations when data is represented in various forms.

operations and use of introductory algebra, probability, and statistics, linking their application to AI. They also exercise visual data interpretation with basic graphs and play with some online platforms that aid in visualization of data in different types.

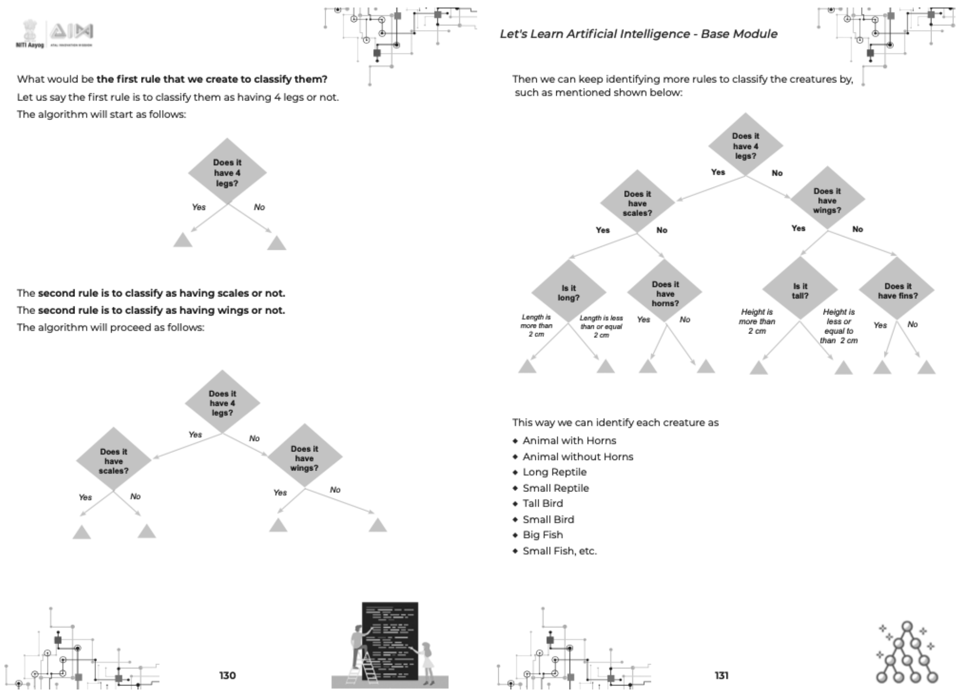
Chapter 5 on problem-solving and decision-making starts with a narrative where the learner is trying to solve a problem by recognizing the factors and using an algorithmic process to make decisions that would solve the problem. Through this narrative, the learners are introduced



12.9 A feature selection and scoring based activity to provide insights into the use of features in AI machines' training.

to the stages of a problem-solving process and allowed to represent the process in terms of algorithms and pseudocode. The later activities introduce the learner to some basic sort, search algorithms as practice and exposure to algorithmic thinking. Figure 12.10 shows an example where the classification algorithm is taught in terms of classification of a set of animals based on some selected features. The chapter closes with an exercise on the algorithmic representation of a classification algorithm.

Chapter 6 is about introducing learners to programming languages, namely Scratch and Python. The chapter points learners toward prebuilt programs to play with and links to external resources for further

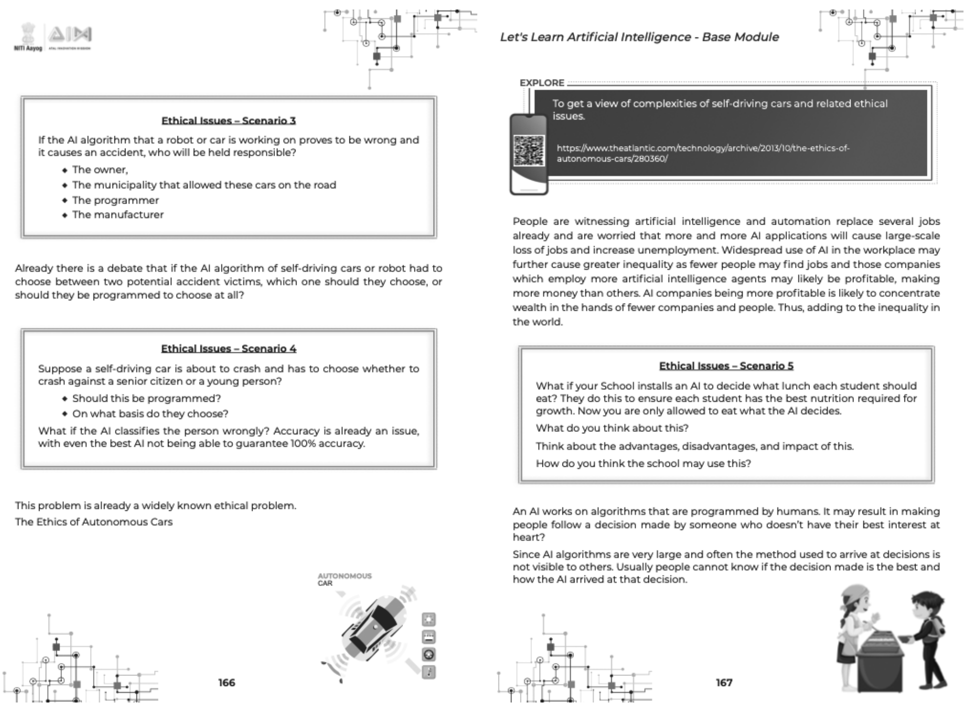


12.10 An example to illustrate classification based on rules represented as a tree.

exploration. The aim is to expose them to two programming basics and allow them to experiment with available codes like a code for smart homes.

Chapter 7 presents the risks and talks about ethics. This is done by posing scenario-based questions to help them reflect how they feel about the issues. The issues cover bias due to data, the concept of privacy, some social dilemmas, and a lot more. The example in figure 12.11 shows individual scenarios given to the learner, enabling them to think about specific challenges that arise with AI. As learners, they would want to be aware of these.

Step-up module The AI step-up module builds on the base module's activities in terms of concepts and the breadth of applicability. This module is also accompanied by a project booklet. This module is available on the AIM's ATL modules webpage or can be accessed with the link https://aim.gov.in/Lets_learn_AI_StepUp_Module.pdf. The details of the step-up module are mentioned as follows.



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Ethical Issues – Scenario 3

If the AI algorithm that a robot or car is working on proves to be wrong and it causes an accident, who will be held responsible?

- The owner,
- The municipality that allowed these cars on the road
- The programmer
- The manufacturer

Already there is a debate that if the AI algorithm of self-driving cars or robot had to choose between two potential accident victims, which one should they choose, or should they be programmed to choose at all?

Ethical Issues – Scenario 4

Suppose a self-driving car is about to crash and has to choose whether to crash against a senior citizen or a young person?

- Should this be programmed?
- On what basis do they choose?

What if the AI classifies the person wrongly? Accuracy is already an issue, with even the best AI not being able to guarantee 100% accuracy.

This problem is already a widely known ethical problem.

The Ethics of Autonomous Cars

AUTONOMOUS CAR

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Let's Learn Artificial Intelligence - Base Module

EXPLORE

To get a view of complexities of self-driving cars and related ethical issues.

https://www.theatlantic.com/technology/archive/2013/10/the-ethics-of-autonomous-cars/280360/

People are witnessing artificial intelligence and automation replace several jobs already and are worried that more and more AI applications will cause large-scale loss of jobs and increase unemployment. Widespread use of AI in the workplace may further cause greater inequality as fewer people may find jobs and those companies which employ more artificial intelligence agents may likely be profitable, making more money than others. AI companies being more profitable is likely to concentrate wealth in the hands of fewer companies and people. Thus, adding to the inequality in the world.

Ethical Issues – Scenario 5

What if your School installs an AI to decide what lunch each student should eat? They do this to ensure each student has the best nutrition required for growth. Now you are only allowed to eat what the AI decides.

What do you think about this?

Think about the advantages, disadvantages, and impact of this.

How do you think the school may use this?

An AI works on algorithms that are programmed by humans. It may result in making people follow a decision made by someone who doesn't have their best interest at heart?

Since AI algorithms are very large and often the method used to arrive at decisions is not visible to others. Usually people cannot know if the decision made is the best and how the AI arrived at that decision.

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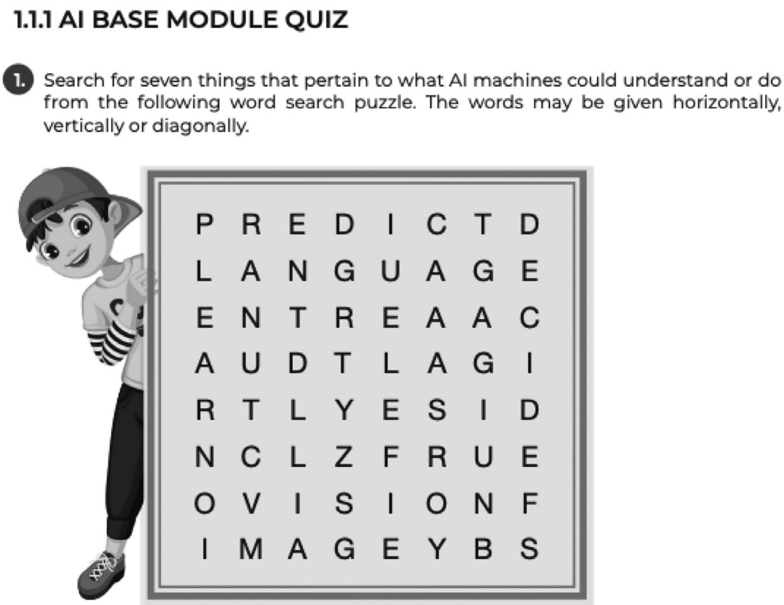
12.11 Examples of scenarios for discussing ethical concerns of AI.

Chapter 1 starts with activities aimed at recalling terms and concepts from the base module. An example of such a recall activity can be seen in figure 12.12. After the activities, there are examples of the use of AI from the domains of health care, astronomy, agriculture, education, entertainment, business, art, data, social media, chatbots, welfare, automobiles, aviation, and deep fakes. The chapter leaves the learners with three ML-based activities like drawing in the air with hands, as shown in figure 12.13, using Scratch-based AI platforms like Pictoblocks (STEMpedia 2020) or ML for kids (IBM ML for kids 2020), where they build programs. The learners are free to choose whichever platform they feel confident or comfortable with.

Chapter 2 builds on the ten considerations of ethics in AI to more structured ethics approach in terms of fairness, robustness, explainability, privacy, and governance. An analogical scenario-based approach has been adopted for delving deep into the topics mentioned previously with



12.12 An activity to recall concepts of the base module.

questions to kindle the learner's thought process. Figure 12.14 shows an example of such a scenario that builds the ground for the learners to understand the concept of fairness.

Chapter 3 talks about machine learning, situating it in the realm of artificial intelligence. The chapter walks the learners through the processes of gathering data, preparing the data, choosing an appropriate model, training evaluation, and parameter tuning. Additional information as videos and reading resources are provided with links to example datasets for the learners to experiment with. Further, the chapter talks about neural networks and deep learning with examples. Enough links to external resources are provided for learners to access platforms that offer machine learning as a service.

Chapters 4 and 5 focus in-depth on the domains of NLP and computer vision (CV) used for solving problems. The chapters introduce the learners to these concepts with examples like spam filtering, chatbots, and sentiment analysis for NLP and self-driving cars, facial recognition, and augmented and mixed reality-based applications for CV. The chapters

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PROJECT: GRAPHICAL PROGRAMMING AND AIR DRAW

In the base module, you were also introduced to graphical programming using Scratch. Let us revisit some of its concepts before we begin our first project.

GRAPHICAL PROGRAMMING AND ITS ELEMENTS

Graphical programming is one of the easiest ways to begin your programming journey. Due to its intuitive interface and programming blocks, it becomes very easy to make games, animations, program robots, and make AI/ML projects. In this module, we will use graphical programming for doing AI-based projects.

Before we jump on to the project, let's first look at the various elements and understand how it works:

Graphical programming (or visual programming) is a method of programming in which the program(s) are written using graphical elements known as blocks. The blocks are like pieces of a jigsaw puzzle that you must put together to solve the puzzle. This approach makes learning to program easy, interactive, and super fun!

You can find more details about the basics of graphical programming at ATL Gaming Module:

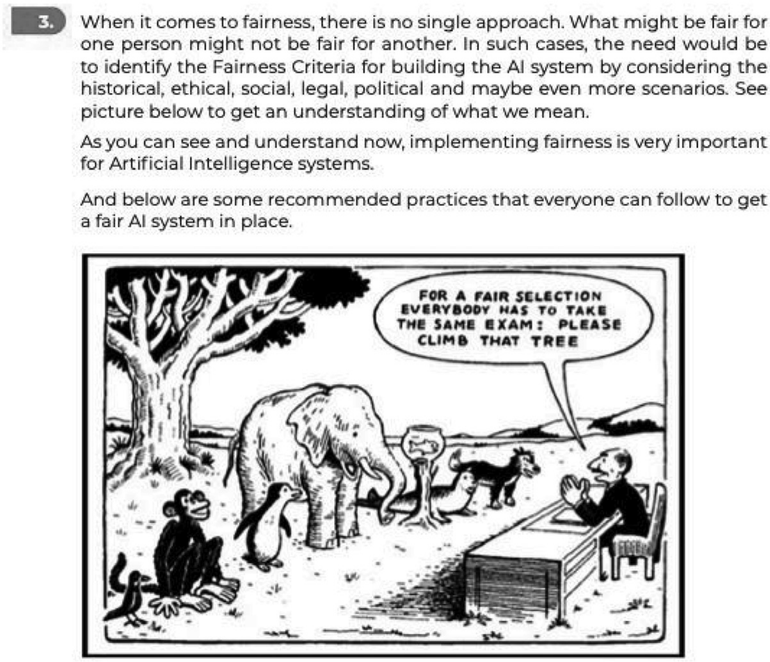
https://atlgamingmodule.in/courseInfo/1

Here's a brief overview of any graphical programming platform:

12.13 An ML-based air drawing activity for the learners.

later focus on the working of such examples and finally close with activities that the students can perform on recommended platforms to develop their own text-to-speech engines and chatbots for NLP and facial recognition systems for CV. All the activities discuss the algorithmic approach and encourage the learners to build them on their own on the given platforms without providing step-by-step instructions. However, the activities have been scaffolded by providing reading links and video links for certain technical aspects.

Chapter 6, 7, and 8 focus on building computational skills of managing data and building programs to manage, refine, and prepare data for various AI algorithms with the help of Python libraries. These chapters delve deep into the nitty-gritty of data management with various



3. When it comes to fairness, there is no single approach. What might be fair for one person might not be fair for another. In such cases, the need would be to identify the Fairness Criteria for building the AI system by considering the historical, ethical, social, legal, political and maybe even more scenarios. See picture below to get an understanding of what we mean.

As you can see and understand now, implementing fairness is very important for Artificial Intelligence systems.

And below are some recommended practices that everyone can follow to get a fair AI system in place.

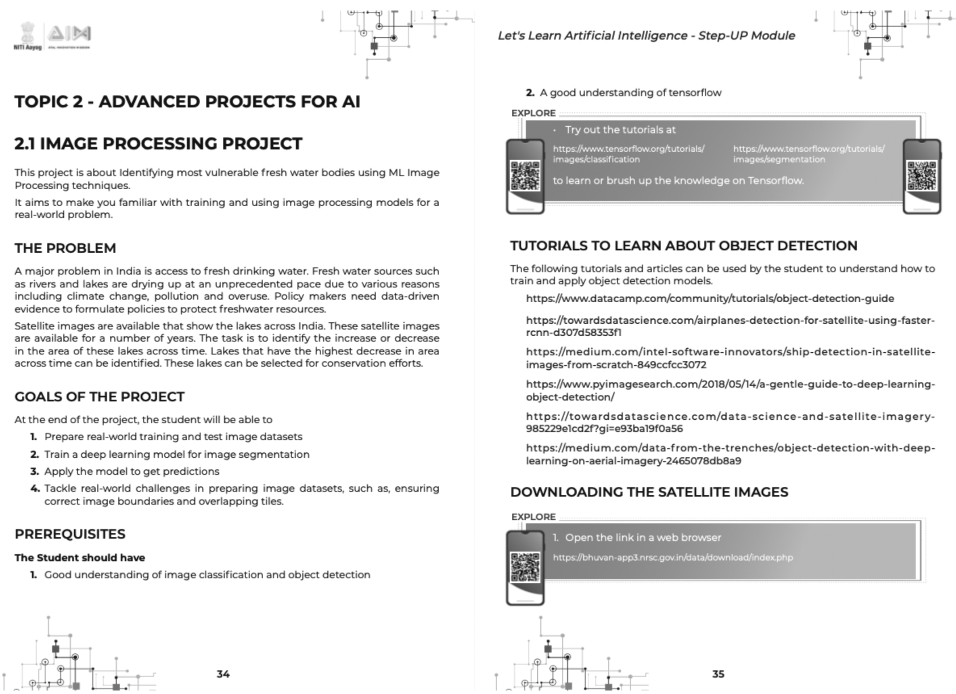
12.14 A scenario to explain the concept of fairness.

forms of databases, using Python's data science libraries, and give the learners basic troubleshooting skills. The last chapter goes into the inner workings of the ML algorithms, allowing the learners to work with supervised, unsupervised, and reinforced learning programming with a few examples from Scratch and Python. These chapters follow a similar activity-based approach and provide pointers toward resources and expertise.

Projects booklet The project booklet was designed as a hands-on manual for learners to try some projects that work on AI. The booklet is available on the AIM's ATL modules webpage or can be accessed with the link https://aim.gov.in/Lets_learn_AI_StepUp_Projects.pdf.

The projects have been divided into two categories. The basic projects use visual programming platforms like adaptations of Scratch for building projects like a rock paper scissors game and a bot using the hardware board called a micro bit available in the ATL labs. The basic platform also includes projects that require the use of AI-based service platforms like Amazon Web Services (AWS) with which the learners build conversational AI interfaces. As for the advanced projects, the book provides two problem statements that are relevant regional problems.

The first one is about identifying water bodies that require conservation as drinking water sources using satellite imagery, as seen in figure 12.15. The second problem is determining the bus routes that can be operated in Bengaluru city while keeping a check on areas that tend to spread Covid-19, as seen in figure 12.16. For both the problems, the data sets are available, and the students have been provided with an algorithmic level of solution to both problems and are encouraged to solve the problems on their own. The learners can also experiment with prebuilt solutions for the given problems, the links to which are also provided. The project book's objective is for the learners to be able to experience the working of AI as part of a solution for a relevant problem, a problem they can associate with.



NITI Aayog AIM

TOPIC 2 - ADVANCED PROJECTS FOR AI

2.1 IMAGE PROCESSING PROJECT

This project is about Identifying most vulnerable fresh water bodies using ML Image Processing techniques.

It aims to make you familiar with training and using image processing models for a real-world problem.

THE PROBLEM

A major problem in India is access to fresh drinking water. Fresh water sources such as rivers and lakes are drying up at an unprecedented pace due to various reasons including climate change, pollution and overuse. Policy makers need data-driven evidence to formulate policies to protect freshwater resources.

Satellite images are available that show the lakes across India. These satellite images are available for a number of years. The task is to identify the increase or decrease in the area of these lakes across time. Lakes that have the highest decrease in area across time can be identified. These lakes can be selected for conservation efforts.

GOALS OF THE PROJECT

At the end of the project, the student will be able to

1. Prepare real-world training and test image datasets
2. Train a deep learning model for image segmentation
3. Apply the model to get predictions
4. Tackle real-world challenges in preparing image datasets, such as, ensuring correct image boundaries and overlapping tiles.

PREREQUISITES

The Student should have

1. Good understanding of image classification and object detection

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Let's Learn Artificial Intelligence - Step-UP Module

2. A good understanding of tensorflow

EXPLORE

- Try out the tutorials at

https://www.tensorflow.org/tutorials/images/classification https://www.tensorflow.org/tutorials/images/segmentation

to learn or brush up the knowledge on Tensorflow.

TUTORIALS TO LEARN ABOUT OBJECT DETECTION

The following tutorials and articles can be used by the student to understand how to train and apply object detection models.

https://www.datacamp.com/community/tutorials/object-detection-guide

https://towardsdatascience.com/airplanes-detection-for-satellite-using-faster-rcnn-d307d58353f1

https://medium.com/intel-software-innovators/ship-detection-in-satellite-images-from-scratch-849ccfcc3072

https://www.pyimagesearch.com/2018/05/14/a-gentle-guide-to-deep-learning-object-detection/

https://towardsdatascience.com/data-science-and-satellite-imagery-985229e1cd2f?gi=e93ba19f0a56

https://medium.com/data-from-the-trenches/object-detection-with-deep-learning-on-aerial-imagery-2465078db8a9

DOWNLOADING THE SATELLITE IMAGES

EXPLORE

1. Open the link in a web browser

https://bhuvan-app3.nrsc.gov.in/data/download/index.php

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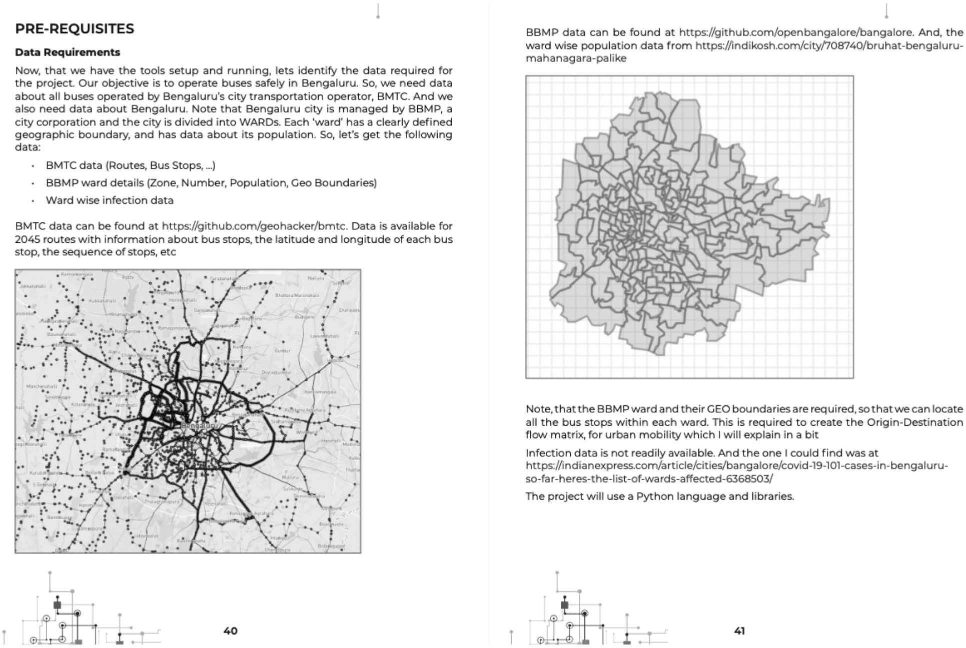
12.15 The drinking water problem statement, prerequisites, and data sources.



12.16 The prerequisites and data sources for the Covid-19 public transportation problem.

The learners are free to choose the scaffolding level, which varies from providing them with a general solution and allowing them to build their ideas as they build their version of the solution to starting with the available solutions and then reengineering them as per their understanding and ideas. This ensures a rich experience and exposure to AI-based solutions that are relevant and situated in real life.

These modules are filled with Blackbox and glass box demos, links, and activities from programmable AI platforms, hardware-based activities, a vast repository of videos along with the formal curricula and content, and external resources. These modules aim at enabling learners to experience AI by providing them with the resources to gain skills. The entire initiative's objective is to get the learners excited about AI, scaffold them toward small achievable goals to keep them motivated, and direct them toward extensively available resources and expertise. We believe that motivated and encouraged young learners scaffolded to deal with the initial complexity via these modules in AI can build their learning paths based on their interests, leading them to develop expertise in the domain.

IMPLEMENTATION

REACH

Through the ATL network, the AI base and step-up modules are now accessible to more than two million students in over ten thousand schools (ATL Schools 2020) spread across India. The majority of these schools are managed by the local, state, or central government and located in underserved and rural regions in the country. The larger aim for the ATLs is to provide equal opportunities to the youth to expose them to human-centric design with AI-based strategies to solve India's economic and social impact issues. These modules are currently aimed at students in grades 8–12 irrespective of their schools via ATLs communities.

An app innovation challenge was launched on October 15, 2020, the birth anniversary of India's former president Dr A. P. J Abdul Kalam, observed as World Students Day. It presented an app development opportunity for students to apply their learnings from computational thinking, physical computing, and AI to solve climate protection problems as well as mental health and well-being and other social problems aligned with the UN's sustainable development goals. One thousand teams consisting of two to three students and ATL school teachers/in-charges/mentors developed mobile-based applications addressing challenges in the key focus areas such as ed-tech, health and wellness, agri-tech, Covid-19 response, sports and fitness, mental health and well-being, and gamification (education and entertainment). A total of twenty-one winning teams were selected (three from each focus area) and were offered necessary tools, technologies, resources, and mentorship support to refine their ideas further and enhance their TRL (Technology Readiness Levels). With this first AI contest organized at a school level considering the quality and quantity of the entries, it is clear that the Indian demographic dividend has the talent and the capability to hone the fundamental skills of AI and implement them to solve real-world problems in tandem with the other skills offered by the ATLs.

TEACHER TRAINING

Teachers in ATLs are to take the role of mentors, who are as important as the modules that have been developed. One of the challenges was building the capacity and the confidence of teachers to deliver and support their learners' quest into the realms of AI. With its beneficiaries' assistance, AIM identified such needs like building confidence in the topic and the pedagogical approach of the modules within the school teachers and educators, in collaboration with its partners is conducting free capacity building workshops every three months. Through such courses by professional trainers, the ATL school teachers and educators gain confidence in the technology. They are able to conduct learning sessions for their students within their schools and nearby communities. This has impacted around five thousand teachers who have enabled another fifty thousand students through their guidance (AIM 2021). The training in AI is in tandem with other skill-based modules like app development modules, allowing the teachers to understand the applicability and potential of AI. Even during the lockdowns of 2020 due to Covid-19, as conducting physical sessions within the Atal Tinkering Labs became a challenge, AIM launched a series of learning modules, guided courses, workshops, contests, sessions, and guest lectures under the ATL "Tinker from Home" campaign. Along with the training, a number of mentor resources are available to the mentors (ATL Curriculum 2019).

The training sessions are also designed on a pedagogical approach that supports tinkering. The teachers wear the learner's hat and explore the concepts by performing the modules' activities. As they build this experience, they try to solve challenges that have been posted as projects in the modules, eventually evolving their solutions. The key idea is to expose the teachers to the concepts and technologies using a pedagogical approach; they are encouraged to follow when interacting with their learners. The approach seems to have built confidence in the teachers in supporting the learners in their explorations with AI, as discussed later in the teacher perceptions.

EVALUATION

As the project is still in its first year of inception, currently we just have anecdotal evidence from surveys conducted among the students and mentors from the pilot ATLs to get to know their perceptions when working with the AI modules as out of class activities or project-based activities. The in-depth evaluations of the various factors of the modules and their impact on the schools across the nation are still in the pipeline. In this section, we share the perceptions of a few students and teachers who were part of the pilot launch.

STUDENT PERCEPTION

The hands-on approach has been appreciated and welcomed by all the students. Students who seemed eager to learn about AI said they enjoyed how concepts were aligned with the activities that helped them relate to the concepts' usage. The students who were not sure about AI said they were attracted by the activities and videos of AI applications, which got them interested in the subject, and then they explored further. In addition to the modules, the learners have acknowledged the roles of mentors/teachers as a support structure who can bridge the concepts and their applications using the available resources at the ATLs. A learner from a school in the state of Gujarat said "it (AI modules in ATLs) helped us learn a lot of different things in artificial intelligence. There were teachers who helped us by guiding the uses of sensors, boards, kits and many more things that we have in our lab. We made several different creative projects from ATL lab. We used project kits to upgrade our knowledge and that knowledge we can apply to different projects of different categories we made in ATL like automated farm, automated home. We used artificial intelligence like using a voice assistant in our home automated project that took the project to the next ultimate level."

The course's low floor high ceiling approach seems to have encouraged students who started with the base module, and some teachers helped with projects, allowing students to experiment and explore further. A public sector school learner said, "The design is excellent, especially for beginners to study and understand the basic and advanced concepts in Artificial Intelligence like Computer Vision, Machine Learning." A lot of students said they felt confident about skills associated with working on projects when working with the AI automated home. For instance, a student from a girl's school in the state of Sikkim said "the step-up module provides various tutorials to work on," and then she later said "working with the AI tutorials have helped in developing critical thinking with collaboration." The students seem confident about their learning and the impact of being able to apply their learnings. Learners from different private and public schools in the state of Gujarat said: "To me, it was a gateway to enter into the world of AI and innovations! Gave me a great experience to learn a new skill!" Another student said, "IT IS AMAZING! It gives beginners an in-hand experience from experts to create something innovative and extraordinary!"

The learners' initial perception of the schools that have been a part of the pilot for AI seems promising in terms of what the learners think about the modules. More perception surveys will eventually be rolled out to the entire nation's schools to get rich insights. In-depth studies will be conducted with learners to understand the impact of the various features of the modules.

TEACHER PERCEPTION

Teachers/mentors play an equally important role. This has also been highlighted in the interactions with the learners. The role of a teacher in the pedagogical design of the modules and ATLs, in general, is more of a mentor than just transmission of information. Their contribution goes beyond concepts to nurture the development of cognitive as well as affective skills. The teachers are motivated and trained with conceptual knowledge and its application, as discussed in the teacher training. Teachers have found the AI modules equally interesting and engaging as the students have. They have appreciated the expertise provided by the industry to the mentors. An ATL in-charge from Gujarat said "the AI setup module established in our lab with collaboration with our mentor at . . . is fabulous. It is so easy to use and gives school children the exposure in this field at such a young age. I, as the in-charge am very happy to learn and teach such technology to my students." Even the mentors have appreciated the concept of a high ceiling and wide walls like providing Scratch- and Python-based examples and activities. As another ATL in-charge from a different school in Gujarat said, "they get to know a language which is helpful like python with machine learning." The modules and the teacher training with the industry have helped the teacher's hold on the subject and its application. They feel confident about delivering the content and supporting the learners in this new journey toward AI. A senior teacher and ATL in-charge from Sikkim said, "The AI modules are something that was long-awaited and much needed to guide the students and more so for the teachers. AI, being a contemporary topic in which teachers like us aren't professionally trained, this module has given us the confidence to handle the subject and deliver the right content and support to the children." she later added, "I trust that it will go a long way in shaping the future generation towards the right direction ahead." Lastly, the hands-on approach has also been encouraged by the mentors. As one of them states, "the modules have been excellent tools for the students to maximize the use of AI, enabling them to create and provide improvised solutions to their community problems. It provides a great resource for hands-on learning of various AI-based projects."

Teacher perception has been promising in terms of the intended impact of the elements and the modules' design. As the community grows, the plan is to have more interactions and understand the challenges that are being faced by the mentors and try to find ways of resolving them by making recommendations for the future teacher training programs and industry interactions. The in-depth studies will incorporate the teachers as stakeholders to gather their insights on the learner's interaction with the modules. Surveys from the mentors will be conducted to incorporate their recommendations for future revisions of the modules.

CONCLUSION

The ATLs initiative has been able to lay the foundation for experiential teaching, learning, and problem-solving using project-based active learning strategies and also building a community of learners and makers. Different modules based on different topics aim to exploit the tinkerability of the environment of ATLs. AI is one among such modules that were built ensuring tinkerability and tinkering ability. This was achieved by using a problem-solving and active learning-based approach that encourages learners toward self-exploration of concepts and strategies. Scenarios close to real-life challenges have been used to provide challenges and a lot of examples and prebuilt projects for the learners to experiment with. The modules provide links to various videos and external resources. The extensive reach of the ATLs in all Indian schools has helped the modules to be accessible to the masses. The modules are available in the public domain from the ATL website for anyone to start learning. As mentioned, a few impact studies are in the pipeline that will provide insights into refining the modules' design and pedagogical approach. Secondly, as the teacher/mentor training is carried out, feedback from them will help improve the modules in terms of content and the pedagogical approach. All the recommendations will be taken into account for the next versions. Meanwhile, the hunt for new tools and platforms that can support teaching and learning of AI will help in incorporation of new tech in the next versions of the modules.

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International Implementations

Edited by: Harold Abelson, Siu-Cheung Kong

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