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# Environmental Sustainability: A Case Study

ProSPER.Net Joint Research Project:
Recycling Plastics in Asian City Environments


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## Case Summary

This lesson plan is comprised of teaching recommendations on the Millennium Development Goals, the Sustainable Development Goals, and the links between human development, sustainable development, and plastic consumption and subsequent waste generation in Indian cities. The linkage of plastic waste to marine litter and its contribution to land based pollution will be discussed. The modules will also provide successful case studies dealing with plastic waste in Indian cities. The course will be based in evaluation of students by quizzes, essays, and exams.

## Learning Objectives

The learning objectives for the course on environmental sustainability with reference to use and management of plastic waste will be:

- To introduce students to the concept of environmental sustainability and its history within the UN development agenda;
- To explain the linkage of environmental sustainability to plastic waste management in urban environment in the context of Indian cities; and,
- To narrate different case studies for successful management of plastic waste within Indian cities.

## Facilitation of Learning

To facilitate active learning of the students, the module will have tutorials and assignments. To meet the learning objectives, there will be three working sessions for the students as described below.

# Working Session 1

This session will begin with defining environmental sustainability and present the context of the Millennium Development Goals (MDGs) as propagated by United Nations (UN) globally.

This session will present the historical evolution of the MDGs and performance of countries in relation to these goals. The United Nations introduced eight Millennium Development Goals (MDGs) in the year 2000 which focused on ***developing*** countries. MDG 7 specifically referred to achieving environmental sustainability by 2015. This MDG had four targets looking at arresting and reversing resource degradation, reducing biodiversity loss, providing access to safe drinking water, and improving the lives of slum dwellers.

The session will then look at evolution of the Sustainable Development Goals (SDGs) which replaced the MDGs in 2016. These are a set of 17 more comprehensive global sustainability goals set by the United Nations targeted at all countries – both ***developed*** and ***developing***. The Goals have 169 targets to be achieved by year 2030. While the Goals 6 (clean water and sanitation), 7 (affordable and clean energy), 11 (sustainable cities and community), 13 (climate action), 14 (life below water), and 15 (life on land) are all tied to principles of a sustainable environment, Goal 12 – sustainable consumption and production – will be the focus of discussion in relation to environmental sustainability within this context.

Assignments should be provided to students in the form of essays on different aspects of progress for the MDGs, effectiveness of SDGs, and the linkage of SDGs to plastic waste production and consumption (Goal 12).

# Working Session 2

This work session will present an overview of growth in plastic consumption and its inherent importance to various infrastructure sectors. The session will also look at per capita consumption in various economies and the growth of per capita plastic consumption in India.

The plastic industry, owing to its use in a wide variety of sectors - such as the automotive, construction, electronics, healthcare, and textile sectors - is amongst the fastest growing markets within India. An analysis by Plastindia Foundation suggests that the industry has grown at a compound annual growth rate (CAGR) of 10%, in volume terms, from 8.33 million metric tonne per annum (MMTPA) in 2010 to 13.4 MMTPA in 2015, and is expected to show a growth rate of 10.5% between 2015 to 2020 to reach 22 MMTPA. This growth would is being further incentivized by various government initiatives, such as Make in India, Skill India, Digital India, and the Swachh Bharat Abhiyan[1]. Figure 1 shows the share of plastic consumption in various sectors within India as of 2012 .

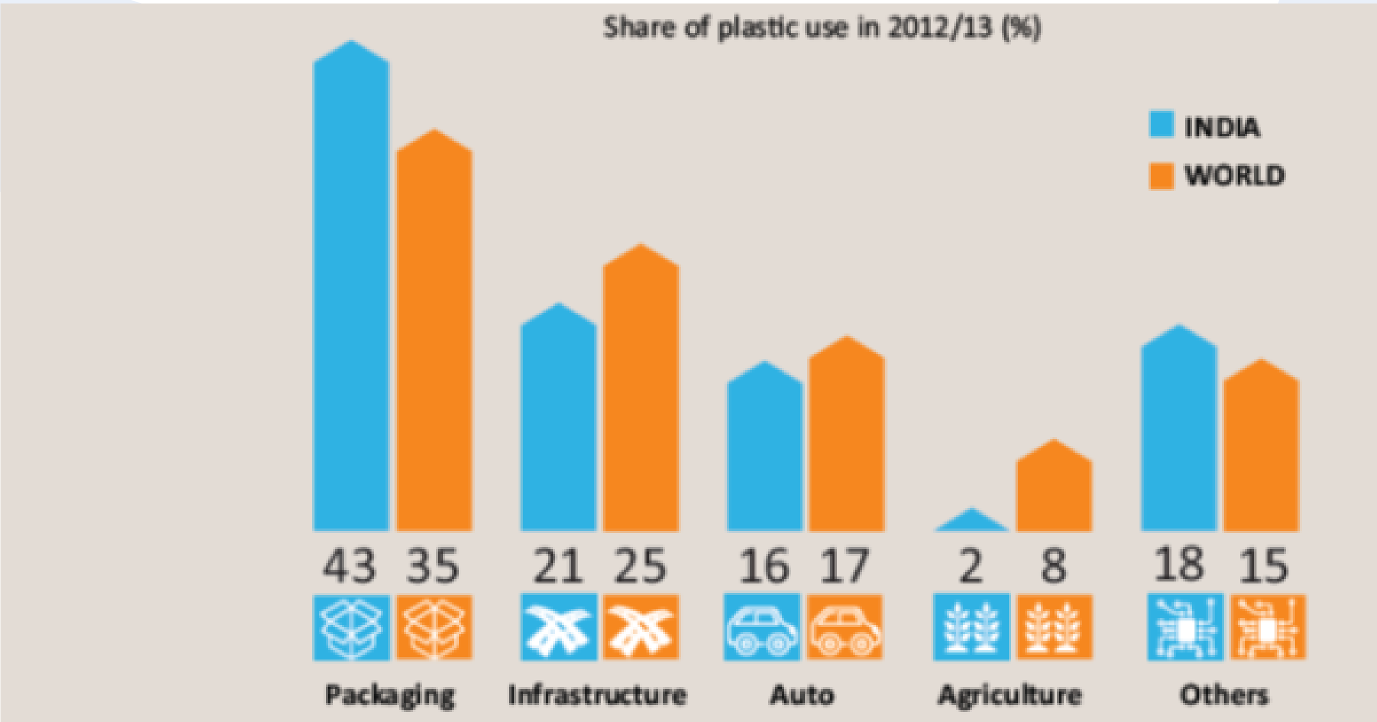

FIGURE 1: Plastic consumption in various sectors
*Source: FICCI*

**Fig 1:** Plastic consumption in various sectors (FICCI).

The statistics clearly show that packaging plastics dominate the consumption of plastics across various sectors, both in India as well as globally. It is this plastic consumption when discarded as waste becomes matter of concern for marine pollution.

However, despite high consumption rates for plastic nationally, the average per capita consumption of plastic in India is about 11 kg per year, which is considerably lower than the global average of 28 kg per year. This is brought into perspective when comparing the rate of per capita consumption with the US, where per capita consumption is nearly ten times that of India (Figure 2). Annual projected growth in packaging plastics is shown in Figure 3.

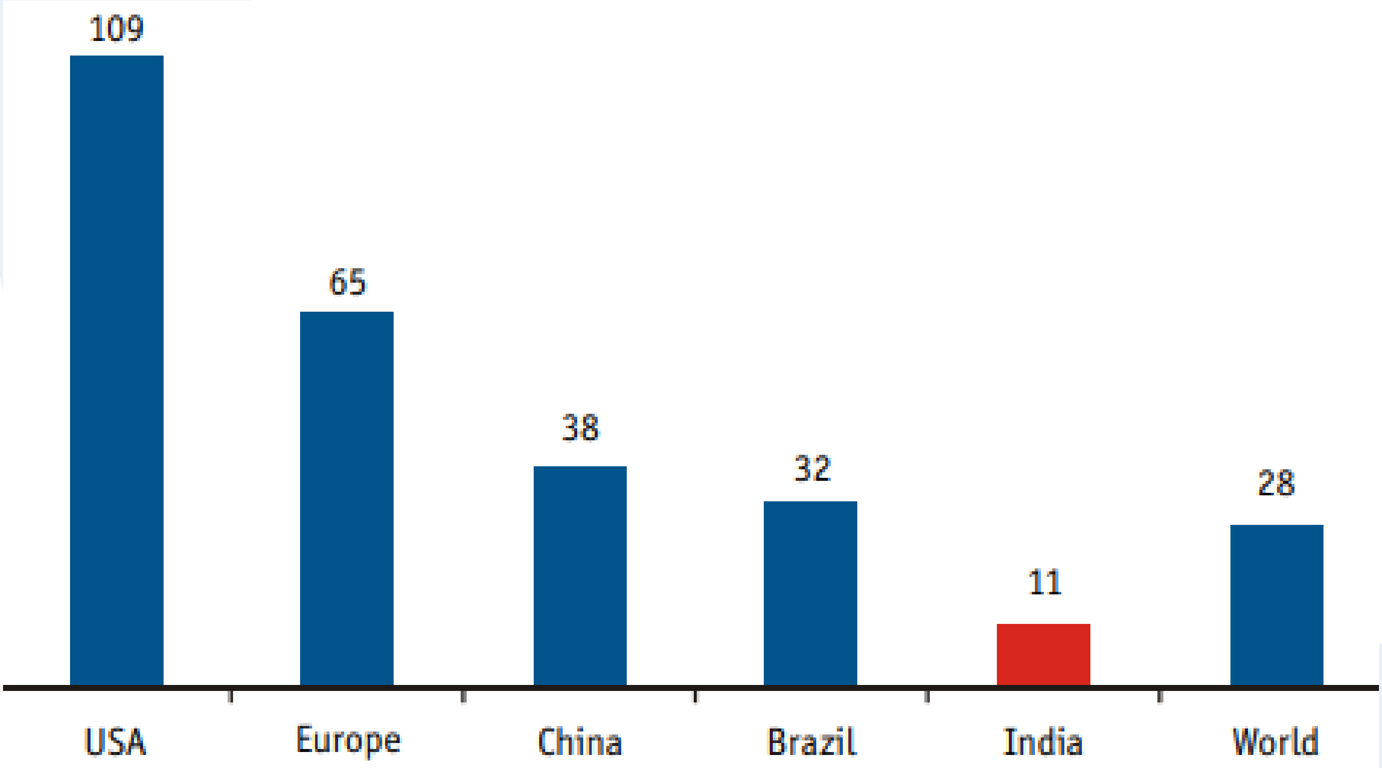


**Fig. 2:** Per capita consumption of plastics across economies (Source: Plastindia, Business press, research by Tata Strategic).

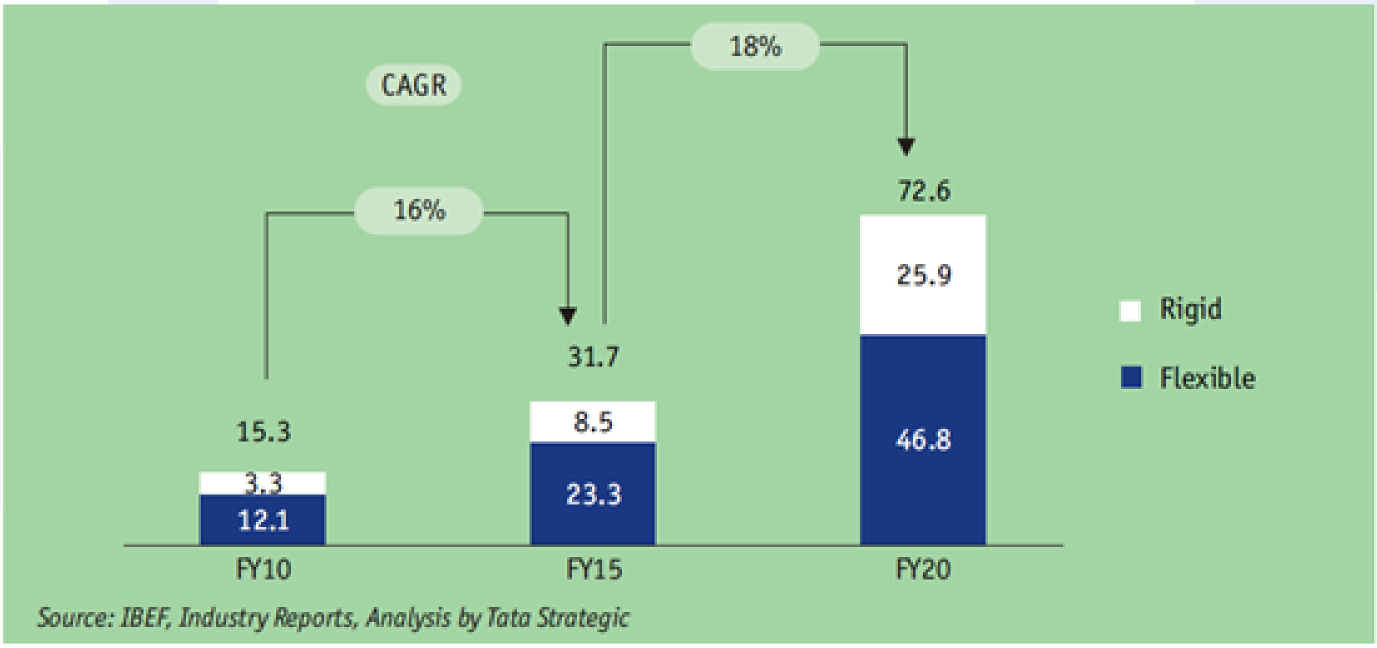


**Fig. 3:** Projected growth in packaging plastics.

The figures above clearly indicate that even though the present per capita consumption of plastics in low in India, it is expected to grow in the coming years as much of the urban infrastructure planned has yet to be established in the country.

Although the burgeoning rates of plastic production are seen as a positive economic indicator for Indian businesses, a cause for concern is the lack of an organized mechanism for dealing with the 15,342 tonnes of plastic waste generated per day within the country. As per the Central Pollution Control Board (CPCB) reports, plastic contributes to 8% of the nation's total solid waste, with Delhi producing the largest quantity for any city in India, followed by Kolkata and Ahmedabad^. While, the report also suggests that 60% of the total plastic waste is being recycled, a major challenge is the segregation and re-aggregation of plastic waste streams such as packaging waste, and especially laminated plastics. Although recycling is one of the preferred ways to deal with plastic waste in the waste hierarchy within India, the concern is that the heterogeneous nature of unsegregated and/or littered waste remains uncollected and scattered throughout urban landscapes. This waste not only produced an unpleasant urban landscape, it chokes drains and releases of greenhouse gases (GHGs) into the atmosphere as they very gradually break down.

Recognising and responding to these challenges, the Ministry of Environment, Forests and Climate Change (MoEF&CC) for the Government of India has created two rules in regards to plastic waste. The **Solid Waste Management** Rules from 2016 focuses on plastic waste as a component of municipal solid waste management, and lays out a prescribed mechanism for municipalities to deal with it. The **Plastic Waste Management Rules** also from 2016 focuses on polyethylene bags and the concept of extended producer responsibility (EPR) to manage the proliferation of plastic bags. Both waste recyclers and waste managers have also evolved innovative ways to recycle/reuse collected plastic waste in Indian cities. The next section describes some of these initiatives.

Various regulatory mechanisms and initiatives taken up by the corporate sector under the provisions of SWM and Plastic Waste Rules under the EPR will also be discussed. The students will be encouraged to take up minor projects in the work session.

This session also discusses issues of marine litter, the contribution of land based pollution to marine pollution, and the linkages between plastic waste and issue of micro-plastics.



^This is as per the CPCB- CIPET survey conducted for 60 Indian cities.

# Working Session 3

The last session would focus on developing action agenda to mitigate adverse impacts of current plastic waste management practices. The session would discuss the case studies of successful management of plastic waste in different application in India. These include:

## Recycling Initiatives

Plastics have a great impact on the environment, but also a great potential to reduce resource consumption thru recycling. Recycling helps to address some of the pre-existing plastic waste problems and saves oil resources (every tonne of plastic waste recycled results in saving approximately 16.3 barrels of petroleum saved) (Stanford University recycling centre). Some of the key product sectors that contain post-consumer plastics include construction, furniture, landscaping, shipping, and soft toys. Scientists from the National Chemical Laboratory in Pune have developed fabric from the recycling of PET bottles. This process is being up-scaled to create fabric that is being used to make T-shirts, scarves, denim, and pillows. In fact, the jerseys of the Indian national cricket team are made out of recycled PET bottles[2].

Blending of these recycled plastics with fillers and additives will enhance the strength and usability of these products, leading to them being value-added products. Blending recycled plastics with fly ash can be used for developing fire-retardant composites with a wide scope of applications. As the current separation of individual plastics at waste sources is currently difficult in Indian cities, recycling of commingled plastics and inclusion of non-halogenated fire-retardant additives will mitigate the problem of segregation to some extent, while leading to value-added products with adequate strength and fire safety[3].

# Bio-based Products

India has a huge potential in producing bioplastics due to the abundant availability of resources. According to a survey by DuPont in India, about 63% of consumers are familiar with bio-based plastics[4]. A study published by Frost & Sullivan (2018) suggests that the annual growth rate of the global bioplastics market was estimated at 44.8% in 2015[5].

Bio-based products can be developed using different techniques and raw materials. One option is using recycled polymeric materials and blending them with biopolymers[6]. Another approach is to develop the composites from only biopolymers without the incorporation of any kind of synthetic polymer[7].

Generally, bio-based products also find applicability in carry bags, super absorbents for diapers, and wastewater treatment. As discussed by Ashter (2016)[8], the market growth of these bio-based and biodegradable plastics is driven by continuous research and developmental activities, increased consumer awareness, consumer preference towards environmental-friendly products, and the implementation of stringent environmental regulations.

The bioplastics market in India is steadily improving and many industries have explored the manufacturing of bio-based products. The J&K Agro Industries Development Corporation Ltd in collaboration with Earthsoul, launched India's first bioplastics product manufacturing facility with a production capacity of about 960 metric tonnes per year. Companies, such as Ravi Industries Maharashtra, Truegreen Ahmedabad, Ecolife Chennai, and Biotec Bags Tamil Nadu are pioneers in the Indian bioplastics industry. Truegreen manufacturing plant has a capacity to produce around 5,000 tonnes of bioplastics products each year. Many start-up businesses are also venturing into Indian bioplastics market such as Envigreen which started its production in Bengaluru and is capable of producing 1,000 tonnes of bioplastics annually.

# Plastic Pyrolysis

Pyrolysis is the breaking down of polymers into smaller molecules by thermal decomposition at temperatures close to 300 °C–400 °C in the presence of a catalyst (such as aluminium oxides, fly ash, red mud, and/or calcium hydroxide) in an inert atmosphere[9]. These kinetic parameters have to be optimized to improve both the quality and yield. Depending upon the process followed, pyrolysis of plastics has an average yield of 45%–50% oil, 35%–40% gases, and 10%–20% tar[10]. A United Nations Environmental Program research report suggests that the yield of oil can be improved (~80%) under controlled reaction conditions[11].

The oil produced in the pyrolysis process shows a high level of similarity to conventional diesel. Therefore, this may be an effective way to recycle plastic waste into fuels. In comparison with many developed countries, India has yet to generate a business model for the conversion of plastic waste to fuel. The Indian Institute of Petroleum, a Council of Scientific and Industrial Research laboratory in Dehradun, has developed a unique process for converting plastic waste, such as polyethylene and polypropylene, into either gasoline or diesel. The technology is capable of converting 1 kg of plastic to 750 ml of automotive grade gasoline.

Rudra Environmental Solutions in Pune, has designed and developed a pyrolysis plant where 1 tonne of plastic waste can be converted to 600–650 litres of fuel at an almost 60% conversion rate. And M K Aromatics Ltd has set-up two plants in Goa to convert plastic waste to fuel.

Hydroxy systems Pvt. Ltd. in Hyderabad has adopted a different technique in the production of fuel oil from plastic waste.  The process which is called depolymerisation involves converting a polymer, in this case, plastic, into a monomer or several monomers. As pasrt of the process, plastic, whih can no longer be recycled, is put in a vacuum chamber along with other ingredients and heated to 350 to 400 degrees Celsius, either by induction heating, microwaving or infrared heating. Post this, it is gasified and an in-line distillation system separates petrol, diesel and high-speed diesel. The by-products of the reaction are petrogas and petroleum coke. It has been claimed that the process is safe, controllable, and pollution-free and also holds the approval of the State Pollution Control Board. The facility has the capacity to convert around 13–15 tonnes of plastic waste per month into approximately 500 litres of fuel.

However, in order to successfully establish a business model to convert plastic waste into fuel for both industrial and domestic use, it will be crucial to develop proper infrastructure and also to create better customer awareness about the fuel potential of plastic waste.

# Gasification of Plastic Waste

Gasification of plastic waste has recently gained increased attention as a thermo-chemical recycling technique. This process involves partial oxidation of plastic waste at high temperatures. The main advantage of this process is the use of air as a gasification agent instead of oxygen alone. This makes gasification a simple technique with reduced operational costs. In this process, hydrocarbon-based materials are oxidized in controlled conditions to produce a gaseous mixture containing carbon monoxide and hydrogen with minor quantities of hydrocarbons[12],[13]. This mixture is known as ‘syngas’ and may be used as a substitute for natural gas. Syngas can be used for heating, lighting, and power generation.

# Use of Plastic Waste in Road Construction

There is a continuous need for enhancing the quality of roads and pavements across India, and the utilization of plastic waste for this purpose is being carried out at various cities in India. The choice of modifier for the road laying process depends on cost and the expected performance. Modification is attained by two main procedures, namely dry processes and wet processes. The waste plastic is blended with aggregates before adding it to bitumen in the dry process, while the wet process involves a simultaneous blending of bitumen and plastic. Better results have been observed for a long time with polymer-modified bitumen[14],[15]. Zorrob and Suparama (2004)[16] reported an increased durability and improved fatigue resistance on the roads composed predominantly of polypropylene and low density polypropylene in bituminous concrete mixtures. The protocol for the road-laying process is simple. Plastic waste is first segregated (chlorinated/brominated plastic waste is excluded) and then shredded to a particular size (2–4 mm). The shredded plastic waste is then added to the aggregate and the bitumen is heated to 160 °C to result in good binding. Jambulingam Street in Chennai was one of India's first plastic roads built in 2002. In 2003-04, the KK Plastic Waste Management Ltd in Bengaluru signed an MoU with the Bruhat Bengaluru Mahanagara Palike BBMP to lay 250 km of roads in Karnataka. As time wore on, polymer roads proved to be surprisingly durable with fewer potholes and edge flaws as reported by the Central Pollution Control Board CPCB, thus receiving support from scientists and policymakers in India and neighbouring countries.

The Indian Centre for Plastic in Environment (ICPE) has been supporting the use of waste plastic in making tar roads. In 2015-16, the National Rural Road Development Agency laid around 7,500 km of roads using plastic waste. Today, there are more than 21,000 miles of plastic roads in India and for every km of road (3.75 m width), 1 tonne of plastic (~10,000,000 carry bags)[17] is used for every tonne of bitumen that is saved. This serves to mitigate plastic waste management considerably and also ensures petrochemical resource conservation.

# Co-processing of Plastic Waste

Co-processing refers to the use of waste materials as an alternate fuel or raw material in industrial processes such  those found as cement plants. Waste materials, such as plastic waste, segregated non-recyclable municipal solid waste (MSW,) and select hazardous waste could be utilized as alternate fuel and/or raw material, thus substituting the use of coal. Cement plants provide an optimum opportunity to balance the act between resource efficiency and waste management. Fossil fuels, such as coal and petroleum coke, have traditionally been used as energy sources in the cement manufacturing industry. However, the use of any of these energy sources calls for an assessment of various factors, such as the availability of processing technology, the economic viability, the potential environmental and health impacts, and the modeled CO2-emission reduction. As such, basic fuel quality requirements need to be carefully considered before using waste as an alternative in cement manufacturing.

Waste materials cannot always be combusted in a cement plant as received, owing to their mixed nature, and therefore must be pre-processed to transform the waste to fit the chemical and physical specifications acceptable to given kilns. Factors to consider when making this decision include calorific and/or material value, water content, ash content, and concentration of sulphur, chlorine, and heavy metals which can affect the overall performance of the cement plant. Therefore, the Central Pollution Control Board (CPCB) for the Government of India has prescribed guidelines on the co-processing of plastic waste in hazardous waste streams as an alternate fuel.[18]

Throughout the course, students should also be required to take part in regular quizzes and minor tests for each work session, with a final comprehensive test. Performance should be evaluated based on class room activities and performance on quizzes, tests, any minor assignments deemed suitable to supplement the course material.

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