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Research and Strategies to Cultivate Safety Awareness and Habits in Students Under the Integrated Teaching of Robotics

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Abstract: The majority of safety accidents in actual production are caused by human beings, among which poor safety awareness and lack of good safety operation habits are the main reasons. Therefore, it is of great significance for schools, as the cradle for talent output, to cultivate the awareness of safe production and safe operation habits among students. Based on the market demand and the safety accidents that have occured in actual enterprise production, the safety problems existing in the integrated teaching of robotics and their causes are analyzed in this paper, putting forward teaching solutions to ensure that students develop good safety awareness and safety habits in schools.

Keywords: Safety awareness; Safety habits; Culture

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1. Introduction

With the advent of the post-pandemic era, the performance of the robotics industry has risen against the tide. According to the latest data released by the National Bureau of Statistics, the output of China's industrial robots by enterprises above designated size rose to 366,000 units in 2021, up 68% year-on-year. At the end of 2021, the Ministry of Industry and Information Technology, the National Development and Reform Commission [1], the Ministry of Science and Technology, and 15 other departments jointly issued the "14th Five-Year Plan" to develop the robotics industry and raise the level of China's robotics industry [2]. According to the outline, China has become the world's largest consumer of industrial robots for eight consecutive years. The increasing popularity of industrial robots signifies the growing market demand for industrial robots. As the cradle of robotics talent output, national technical colleges play a pivotal role. Safety is the priority in the training of robotics talents. Poor safety awareness and safety habits are the biggest hidden hazards in actual enterprise production [3]. The primary cause of safety accidents in major factories and enterprises is the operators' lack of safety awareness and good safety habits. Therefore, under the background that all walks of life attach importance to safety in actual production, the primary task of schools, as a place for talent output, is to cultivate good safety awareness and safety habits among students.

2. Safety problems in the integrated teaching of robotics and their causes

In the integrated teaching of robotics, safety comes first. The importance of safety is widely recognized. Robotics is often the core course for students majoring in electromechanical integration, electrical

automation, and industrial robots [4]. Therefore, it is particularly important to learn this course well. Since these students are frequently operating such equipment, teachers need to ensure that the students can complete this course safely. Although the robotics course is alike any other professional courses, its safety problems are evident.

2.1. Safety awareness

Students who have been exposed to robotics from their working experience are few in number. For the majority of them, it is basically their first time encountering robotics. Hence, the students who taking this course are generally unaware of the safety issues in robotics. This new generation of students, born after the year 2005 [5], have been surrounded by love from their family, relatives, and friends since childhood. They tend to have many yearnings for things and are unaware that it may be unsafe at school. It is precisely the lack of awareness of safety that is likely to cause safety accidents.

2.2. Personal safety

When students operate industrial robots, personal safety injuries, such electric shock and impact injuries, may occur. The power supply voltage of such robots is generally between 220 V and 380 V but the input and output voltages of the control terminal are 24 V [6]. Students are unable to differentiate the lines between safe and unsafe as they are unfamiliar with the hardware wiring of such equipment. Impact safety injuries, on the other hand, mainly refer to injuries that occur not by mistake outside the safe distance during the movement of the robot. The strong impact may result in personal safety injuries among students.

2.3. Equipment safety

In the integrated teaching of robotics, other than the personal safety of students, equipment safety should also be guaranteed. The four foreign brands of industrial robots that are commonly seen in teaching equipment account for more than 70% of the global market share. By learning how to operate them, students would find it easier to look for jobs in the future. Robots of foreign brands are generally more expensive than those of domestic brands; the price of one robot is at least one to two hundred thousand Yuan. Each equipment will be shared among four to five students given that there are ten equipment in one training site. On the premise of ensuring the personal safety of students, it is also necessary to ensure the safety of equipment. When a robot is not operated correctly or the speed of the robot is too fast, the robot may collide and damage the surrounding equipment and its own body. In such cases, the equipment may be easily damaged, and property losses may be incurred. The cost of repair is relatively high, so it is necessary to send the equipment or its accessories to the original factory for regular maintenance. However, this will result in inadequate equipment available, thus increasing the ratio of student to equipment, and in turn slow down the progress of teaching and affect both the teaching and learning process.

2.4. Safe operation habits of industrial robots

When operating industrial robots, many students do not have a good habit of practising safe operation. For example, some students do not wear safety helmets and tend to increase the speed and operate the robots on their own without following the rules set as they are eager to complete the tasks assigned by their teachers. They have a weak sense of safety and tend to put their heads into the robots to obtain certain materials. Being impatient and carrying out improper operations may result in impact injuries. Besides, there are some students who do not like to hold the teaching device in their hands; thus, they are not ready to press the emergency stop button at any time. Once a program is written, the students tend to execute it immediately. Transition points tend to be missed with careless programming, and the robots may collide if any one transition point is missing.

3. Strategies to solve safety problems

In view of the aforementioned safety problems in the integrated teaching of robotics, several strategies are proposed.

3.1. Safety education

The first lesson of the robotics course should include safety education and training. In order to achieve the goal of strenghtening students' awareness of safety, it is necessary to select typical cases with strong pertinence in order to enhance students' interest and risk awareness, so as to leave a strong impression in their minds and establish a sense of safety and responsibility among students when operating industrial robots [7]. A typical case of personal safety accident caused by the operator's negligence, carelessness, and weak sense of responsibility is discussed below.

In an automatic production line of a ceramic tile factory, an industrial robot was stacking ceramic tiles on the production line. A worker walked into the robot stacking area and turned his back toward the robot. At that time, a phone call came in. The worker did not notice the robot behind him and turned his attention to his phone. When he took out his mobile phone to answer it, the robot turned in the direction of the worker, pressing the worker's head under it (**Figure 1**). The worker was killed on the spot. When the other workers saw what had happened, nothing could be done.

Figure 1. Safety accident site

From this case, we can see that the worker did not have any safety awareness, neither did he take any measure to ensure his own safety, such as wearing a helmet; furthermore, there were no instructions on how to run the operation area of the industrial robot. In addition to the weak safety awareness of the worker, the production line equipment also lacks safety measures. Around the operation area of industrial robots, isolation barriers should be set up, and workers without a key should not be allowed to enter; the guard rail should be equipped with necessary access doors and openings, along with safety pins, safety locks, photoelectric protection, and other safety devices [8].

In addition to introducing typical cases of safety accidents in factories, teachers should also inform the students of the power supply voltage of the equipment and the source of the power supply; they should also conduct on-site demonstration during safety education and training so that the students would know how and where to cut off the power supply in case of any electric shock accident. Other than that, teachers should also conduct a demonstration on how to wear a safety helmet, operate industrial robots with the teaching device, and use the emergency stop button on the device [9]. Students should be taught on how to deal with emergencies, such as electric shock accidents and robot collision accidents, and be instilled with the idea that safety is no trivial matter and carelessness may likely cause safety accidents.

3.2. Establish a training site safety system

Training rooms are important for practical teaching, vocational skill training, skill identification, and vocational qualification certification. Most of the time, a safety system is established based on the safety requirements of the training site and equipment. The rules and regulations embodied in the safety system are then put up at the entrance of the training room [10]. Clear safety warning signs should be attached on the doors of the equipment, and professional workshops that emphasize on safety precautions should be arranged for students so that they can learn and familiarize themselves with the safety system of the training site and know what can or cannot be done.

3.3. Establish safety operation specifications for industrial robots

(1) Preconditions for safe operation

Students must wear labor protection articles and safety shoes as required before operating any equipment to prevent injuries. Safety helmets and safety work clothes should be worn to prevent abrasions or lacerations that may result from contact with sharp corners or when operating the end tools of industrial robots. Other than that, protective gloves and eyewear should also be worn as required by the task to avoid injuries to the hands or eyes from splashing. Their dressing should be checked before class, and during practice, the isolation area should be separated. All students should wear their safety helmets correctly when entering the practice area. Otherwise, they should be prohibited from entering the area.

(2) Safety operation specifications

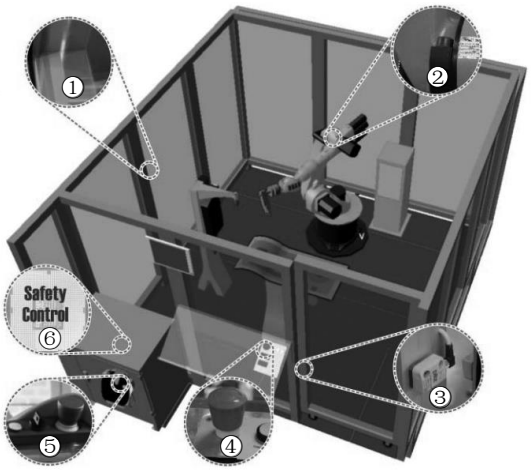
Students must be familiar with the safety operation specifications and strictly follow them. If any student fails to follow the specifications, the teacher should guide them [11]. It is prohbitied to start the robots when anyone is moving in the work station. When programming, it is crucial to pay attention to the running track of the robot and whether or not the grab and pipeline package collide. After programming, it is necessary to manually run it slowly to ensure that the program track is correct as well as pay attention to the pneumatic system and live parts. Students should be aware of the danger of the residual electricity on these circuits even after the power is cut off. When working at the welding station, it is compulsory to wear protective eyewear, and students should not look directly at the welding position. The smartPAD teach pendant should be treated with care. When not in use, it should be neatly hung on a special bracket so that it does not fall by accident. Students should also pay attention to the clamping cylinder state of the tooling table and transfer table. When the station is running, the initial state must be open. When completed, the robot control system should be shut down, and appropriate measures (such as padlocking) should be taken to prevent unauthorized restart. When operating in the control cabinet, the operator must wait for 5 minutes until the intermediate circuit has been completely discharged [12]. When the operation or maintenance personnel leaves the work site, the voltage of the power line must be cut off. Signs indicating that work is being carried out should be hung on the equipment, even when the operation is stopped temporarily. When disassembling sheet parts, labor protection gloves should be worn to prevent injuries from sharp edges.

3.4. Increase the number of teachers

As industrial robots are equipped with both strong and weak currents, students are at risk of electric shocks at any time during practice. Generally, the number of students in a class is between 35 and 45. If only one teacher is present during the class, the risk of safety problems occuring may be higher [13]. Therefore, the site should be equipped with an assistant teacher in addition to the keynote teacher. In this way, when one teacher is explaining or answering questions posed by a student, the other teacher would be able to monitor the other students.

3.5. Establish the awareness of safety devices

A robotic system must be equipped with an appropriate safety device, which includes an isolation protective device (guardrails, doors, *etc*.), emergency stop buttons, braking device, shaft range limiting devices, *etc*., as shown in **Figure 2**.



① Fence
② Mechanical end stops or shaft range limiting devices for shafts 1,2, and 3
③ Protective door and door contacts with closing and monitoring functions
④ Emergency stop button (external)
⑤ Inside the emergency stop button, confirm key, call connection manager key switch
⑥ Built-in (V) KR C4 security controller

Figure 2. Safety device

An incomplete safety device may cause bodily injuries or property losses when the robotic system is operated. Therefore, the robotic system should not be operated when the safety device is removed or turned off. Guard rail is an indispensable isolation device for robots. Its function is to prevent non-robot operators or visitors from entering the working range of robots, which may lead to injuries or property losses. When an operator accidentally goes over the protective fence, which threatens his/her safety, it serves to warn the operator. On the other hand, the external emergency stop button is a safety button that is connected to the customer or supplier through the input end of the interface in addition to the existing emergency stop button on the KUKA control panel (KCP) to ensure that the emergency stop device is available even when the KCP is unplugged. Door contacts with closing and monitoring functions are installed on the protective door. They serve as safety protections set to prevent the robot from entering by mistake under automatic and external automatic operation modes. The emergency stop button is usually located on the KCP and can be pressed in case of any danger or emergency [14].

The safety device of the robotic system should be discussed during class. Typical safety accident cases can be taken as examples to illustrate how miserable a robotics operation would be without safety devices [15]. When preparing students for work, teachers must help students develop a strong sense of safety. This includes not only the safety of people, but also the protection of equipment.

4. Conclusion

In China, many people are now engaged in the robotics industry. Any negligence in factories may cause irreparable losses or even casualties. Therefore, it is compulsory for anyone engaged in the robotics industry to receive professional training; any untrained personnel should not be allowed to work in this industry. It is of great significance to instill the safety norms and safety awareness of robotics into students during lessons so that they can develop good safety awareness and habits. Sooner or later, these students will begin working for enterprises that deal with such equipment for actual production. Their lives would be more secure if they were to retain a strong sense of safety from their time in school.

Disclosure statement

The author declares no conflict of interest.

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