Teaching Reform of Computer Vision Course in the Context of Artificial Intelligence

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Abstract. This paper explores the teaching reform of the computer vision course from the perspective of the "student-centered and application-focused" construction criteria of China's "Emerging Engineering Education." We propose a "Four modes Three Stages" reform model. The reform is implemented in four phases: optimizing teaching contents and resource allocation, innovating teaching modes and means, bolstering students' practical exercises, and nurturing students' academic research skills. Practice demonstrates that this strategy may overcome the constraints of conventional education content and methods and build artificial intelligence talent to meet the demands of innovation and practice.

Keywords: computer vision · reform model · application-oriented · teaching reform

1 Introduction

In recent years, the rapid growth of artificial intelligence technologies has resulted in enormous societal changes. Significant fields such as industrial control, agricultural production, intelligent healthcare, traffic information, intelligent robots, and mobile Internet have been permeated by artificial intelligence, promoting social and economic development in all aspects. As one of the critical majors in constructing "Emerging Engineering Education" in colleges, the artificial intelligence major plays a vital role in integrating various professional disciplines. As one of the most important majors in developing "Emerging Engineering Education" in colleges, the artificial intelligence major plays a crucial role in integrating multiple professional disciplines. As one of the required professional courses for artificial intelligence majors, "Computer Vision" focuses primarily on how machines might be used to "see" the human environment. Teaching students how to perform intelligent feature extraction on collected images or videos, as well as how to use traditional machine learning or modern deep learning algorithms to develop applications such as image recognition and classification, target detection, object tracking, and multi-modal semantics analysis of images and texts, is the primary objective of the undergraduate level of the artificial intelligence major.

Based on the concept of China's "Emerging Engineering Education" construction plan, this paper explores the teaching reform method of undergraduate computer vision courses from the standpoint of artificial intelligence. The research is student-centered,

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intending to improve students' ability to practice and innovate in new technologies and industries. The specific method is optimizing course teaching content in conjunction with industry technology development trends and integrating interdisciplinary applications. We want to address some outstanding issues in the course teaching process that have emerged in recent years, such as incorrect content positioning and design, ineffective traditional teaching methods, and a lack of interdisciplinary applications. Computer vision talents with strong application innovation abilities are cultivated through this reform.

2 Problems

Computer vision is a new discipline developed based on image processing. The course content is broad, the theoretical complexity is high, and it involves multiple disciplines. The course's teaching must keep up with the demands of academia and industry applications. Furthermore, due to the short discipline construction time and lack of experience, it is necessary to refer to industry development and the construction experience of well-known universities to carry out teaching reform.

2.1 Development Status of Computer Vision Technology

Computer vision, one of the most popular artificial intelligence research fields, is widely used in various fields. It has evolved from two-dimensional image processing to three-dimensional video processing and then to real-space detection from the 1950s to the present. The operation method has also shifted from three-dimensional space construction to feature recognition. The algorithm has evolved from traditional feature engineering-based methods to big data-driven, deep learning-based computer vision methods. With the rapid development of computer software and hardware and the acceleration of computer technology from theory to application, many high-quality visual data sets and algorithms have emerged, and many traditional methods have been further optimized. Deep neural network-based methods have advanced performance in areas such as image classification and segmentation, target detection and recognition, and multi-modal fusion semantic analysis of graphics and text. Interpretability in application scenarios is also gaining popularity. Our proposed "Four modes Three Stages" reform model is shown in Fig. 1.

2.2 Research Status of Teaching Reform on Computer Vision Course

Because of the widespread use of computer vision technology in a variety of fields, domestic and international universities initially only offered this course at the postgraduate level. However, it is now available at the undergraduate level. This course is one of the most important professional compulsory courses for newly opened artificial intelligence majors in recent years. It is generally designed for 72 credit hours, including 54 credit hours for theory and 18 credit hours for experimentation, totaling 4 course credits.

At present, domestic and foreign experts and scholars have carried out some exploration and research on the teaching reform of the course, such as: introducing the course ideology and politics into teaching [1], innovating teaching methods [2], improving experimental methods [3], and integrating the concept of "new engineering" into practical training [4]. These reforms have improved teaching quality to some extent, but they do not constitute a complete system. Computer vision, as a new course with strong theory and practice, has a short course time and the following problems:

The textbook is not suitable for the learning situation. Some schools choose foreign classic textbooks, such as Carsten Steger's "Machine Vision Algorithms and Applications", Simon JD Prince's "Computer Vision Models, Learning and Reasoning", etc. These textbooks cover a wide range of content, focusing on the mathematical theory behind vision algorithms and lacking practical experiments close to daily life applications. Undergraduate students are more difficult to learn, and it is easy to "dissuade" students at the learning level of mathematical knowledge. Some colleges and universities choose textbooks from training institutions. These textbooks are more hands-on and practical, and the cases are more in line with real life, but they often list too many codes in the textbooks, ignoring the teaching of algorithm theory; in addition, these textbooks are often customized in combination with the special software and hardware platforms which is custom-built and invisible to students. Students often have no way to deal with practical problems when they can't use the platforms. Some other textbooks usually describe traditional classical algorithms and lack the extension of cutting-edge new technologies.

- The interdisciplinary integration characteristics of the curriculum are not fully reflected. Computer vision has a wide range of application scenarios in many fields such as intelligent transportation, smart medical care, and intelligent manufacturing. However, the teaching cases currently taught are mostly conventional teaching cases such as simple natural image classification and face recognition. The cross-disciplinary comprehensive case is still less.
- The teaching mode is outdated. Teacher-centered "cramming" teaching focuses on teachers' teaching while ignoring students' differences in learning, so some students lose interest in learning because they can't keep up with the pace of teaching. In addition, the courses usually adopt the teaching mode of traditional computer courses. The theoretical courses and experiments courses are separated. The teaching effect is not ideal. In the whole process, it is difficult to form the internalization and extension of knowledge, students' active participation is low, and it is difficult to form a sense of self-learning [5].
- The examination method is single. In the course of classroom teaching, various forms of evaluation have been carried out, such as online learning, classroom tests, and final exams. However, the effect of teaching improvement still needs to be improved. The evaluation results cannot promote the development of students well, and fail to stimulate the continuous improvement of teaching and learning.

To sum up, under the background of "new engineering", how to reform the computer vision course to keep pace with the times is an important problem that needs to be explored and solved urgently in the training of artificial intelligence major.

3 Methods

Computer vision technology can be decomposed into three levels: image processing at the bottom layer, feature extraction at the middle layer, and image analysis at the upper layer [6]. Basic low-level vision technology mainly includes image acquisition, enhancement, and restoration. The middle-level vision technology mainly includes feature extraction based on traditional operators such as SIFT, HOG, and SURF. High-level vision technology mainly includes image classification and segmentation, target detection and racking, Autoencoders and generative adversarial networks, motion estimation, multimodal semantic understanding, etc. Both the undergraduate and postgraduate courses of artificial intelligence majors offer computer vision courses, but their course orientations are different. At the undergraduate level, the course focuses on some basic principles and methods of computer vision, so that students can understand the development history of computer vision and understand the current field. At the postgraduate level, the curriculum system needs to reflect professionalism and cutting edge. In addition to the introduction of low-level vision, it is also necessary to focus on middle and high-level visual knowledge. explain. Judging from the research on the artificial intelligence employment market, even for undergraduate graduates, employers need graduates to understand cutting-edge hotspots and grasp the trend of research and application. Therefore, in the teaching process, it is necessary to optimize the teaching content and mode design, and systematically implement teaching reform. The proposed "Four modes Three Stages" reform model is shown in Fig. 1.

3.1 Optimization of Teaching Contents

In response to the problem that the teaching content is not suitable for the learning situation and technological development, we put forward the following three suggestions for improvement: First, in terms of traditional theory, considering that students majoring in artificial intelligence have completed digital image processing, machine learning, and deep learning courses, we delete some content or algorithms that are repetitive, outdated, inefficient or ineffective in practical applications, and introduce some widely used or the latest algorithms to keep the teaching content updated. For the traditional computer vision part, it is not the focus of our teaching, but only the consolidation and transition of the predecessor courses. At the same time, some parts of the content are needed to be optimized. The specific optimization design is shown in Table 1. Some of the traditional machine vision teaching content is compressed in the design, especially the "feature extraction + classifier" mode has now been perfectly replaced by deep learning methods. Only theoretical reviews and projects are carried out on this part of the content, and no algorithmic details are deduced. In terms of content design, reducing content does not mean not talking at all. In the teaching process, the connection between traditional vision and deep learning can be strengthened, for example: by combining data expansion and transfer learning in deep learning in the explanation of geometric transformation, and using it in the project. As a classic classification model of machine learning, SVM is still widely used today, so it is necessary to carry out more exercises. For the traditional teaching emphasis such as gray difference statistical texture features, local binary pattern (Local binary pattern, LBP) series of texture description algorithms are used instead.

Table 1. Optimization of traditional computer vision teaching content

Theoretical classification	Knowledge	Content optimization
Image Processing	Image geometric transformation	Add image translation, rotation, scaling, and mirroring to supplement image augmentation methods in deep learning
	Spatial enhancement of images	Introducing Image Smoothing and Sharpening Combined with Convolutional Kernels in Convolutional Neural Networks
	Frequency Domain Enhancement of Images	Reduce Fourier transform, enhance frequency domain, and supplement graph convolution appropriately
	Morphological processing of images	Reduce content, review in comprehensive case
Image compression and restoration	image restoration	Reduced content, introduced in Deep Learning Super-Resolution Reconstruction in Progress
	Image Compression	Reduced content, introduced in Autoencoders
Feature extraction and classification	Image feature extraction	Briefly review statistical features such as LBP, SIFT, and HOG, and add a series of methods such as color correlation diagram, shape context, and local binary mode.
	image classification	Introduce SVM in combination with project cases, and delete the content of the BP neural network, clustering, decision tree, etc.

Secondly, when deep learning technology is dominant in computer vision today, it is necessary to keep up with the pace of technological development, focusing on teaching computer vision technology based on deep learning theory, and its content optimization design is shown in Table 2, including fully connected neural network, classic convolutional neural network, applications such as network models, target recognition, image segmentation models and generative adversarial networks. In the teaching process, the construction of deep neural network models, data enhancement, network parameter fine-tuning, and training visualization are comprehensively explained, which guides students to master the visual tasks and can design deep neural networks to solve practical problems.

Third, in response to the lack of interdisciplinary integration in the previous teaching, we design a project case library to improve students' ability to integrate what they have

Table 2. Optimization of computer vision teaching content based on deep learning

Theoretical classification	Knowledge	Teaching content design
deep network model	Fully connected neural network	Combined with MNIST handwritten digit recognition to review the back-propagation algorithm, compare the network classification effects of MLP and CNN
	Convolutional Neural Network	Combined with natural image classification tasks, learn the design concepts of classic CNN models such as LeNet, Alex Net, GooLeNet, ResNet, and DenseNet and become familiar with deep learning frameworks such as Pytorch in the process
	Object Detection Model	Introduce the R-CNN series focusing on teaching FasterRCNN, Introduce the technical evolution of the YOLO series, focusing on teaching YOLOV3
	Image Segmentation Model	Introduce FCN, DeepLabV3, and PSPNet, and focus on UN et
	Generative Adversarial Networks	Introduce the mathematical principles of GAN, focusing on CycleGAN, Conditional GAN
Model training and optimization	Data Augmentation	Focus on data normalization, random geometric transformation, color transformation, random noise, introduction to GAN enhancement
	Model Training	Network parameter initialization, hyperparameter search, and optimization, loss function, optimizer, regularization, label smoothing, early stopping mechanism
	Model Compression (Introduction)	Model pruning, quantization, distillation, neural network search
	Model Visualization	Focus on the use of torchsummary, tensorboard, and visdom, introduce Gram-CAM
Deep Learning Framework	Deep Learning Framework	Mainly using Pytorch, introducing PaddlePaddle and TensorFlow

learned to deal with interdisciplinary problems. The training items are shown in Table 3.

Fourth, we need to introduce the latest research results in the field of computer vision to innovate the teaching content. The specific content is shown in Table 4. We broaden students' academic horizons through tutoring and interest groups.

3.2 Innovation of Teaching Mode

Under the background of "Emerging Engineering Education", course teaching needs to adhere to the OBE concept of "student-centered, output-oriented" for teaching model innovation. Based on consolidating basic theory, attaching importance to hands-on practice, and increasing case training, the teaching reform is explored by constructing experimental platforms, reforming the teaching mode of courses, strengthening foreign cooperation, and optimizing assessment methods.

- Build an experimental platform. Modern computer vision technology based on deep learning requires the support of big data and large computing ability. The course adopts standard GPU workstation configuration and provides students with the use of rented cloud computing servers to rationalize the use of resources. Teaching adopts the Pytorch framework, which is currently the most widely used deep learning framework for teaching and project practice. In addition, considering that in the previous teaching process, students lacked the training in model deployment in engineering practice, we deploy a certain amount of Raspberry Pi development kit, NVIDIA Embedded boards Huawei Atlas embedded platform to allow students to familiarize themselves with the whole process of model design, training, and terminal deployment.
- Reform the curriculum teaching mode. First of all, learning basic knowledge in the way of interactive programming teaching, dilute the boundary between theoretical courses and computer-based experimental courses, which can closely combine teaching and practice. Second, use project-driven teaching to improve students' ability to use computer vision technology to solve practical problems in comprehensive cases. The project will show students the procedure of project development from the whole process of data acquisition, data preprocessing, data annotation, model selection or design, model training, hyperparameter optimization, model prediction, model deployment, and document creation. At the same time, based on the benchmark model provided by the teacher, students are encouraged to form teams freely, use what they have learned to optimize each link of the development of various computer vision projects, and conduct seminar-style defenses, to stimulate students' spirit of exploration and innovation. Third, through extracurricular academic expansion, students can exercise their ability to read scientific research literature, so that students are not limited to teaching content, maintain enthusiasm for continuous learning, and can grasp new technologies and new ideas in the industry. Fourth, students are encouraged to study computer vision courses from internationally renowned universities online courses, such as CS231n from Stanford University and Computer Vision MOOC from Columbia University.

Table 3. Course Comprehensive Case Design

Theoretical classification	**Cases**	**Difficulty**	**Knowledge**
traditional vision	Answer Card Identification	★	Image filtering, edge detection, binary processing
	License Plate Recognition	★	Contour detection, contour approximation, optical character recognition
image classification	CIFAR-10 Classification	★	Data reading and visualization, implementation, and parameter selection of classic CNN models
	Identification of Agricultural Pests and Diseases	★★	Data collection and production, data augmentation, model selection and optimization, model deployment and design
	Chest X-ray Disease Classification	★★	
Target Detection	Past Competition Experience based on Kaggle	★★	Model design optimization, using pre-trained models for transfer learning, and mutual learning
	YOLO3 Emotion Detection	★★★	Adaptation of models to actual tasks, collection and labeling of datasets, optimization of model indicators, and model deployment
	Chest X-ray Lesion Localization	★★★	Students participate in teachers' scientific research projects, and scientific research results enter the classroom to understand the problems and solutions encountered by the standard model in solving practical problems
Image segmentation	Past Competition Experience Based on Kaggle	★★	Use of FCN, PSP, DeepLab

(*continued*)

Table 3. (*continued*)

Theoretical classification	**Cases**	**Difficulty**	**Knowledge**
	UNet Fundus Vessel Segmentation	★★★	Reproduce the results of scientific research papers and master the network principles of UNet and UNet + +
Generative Adversarial Networks	Handwritten Digit Generation	★	The principle and use of GAN
	Cartoon Avatar Synthesis	★★	The principle and use of CycleGAN

Table 4. New teaching content in the academic expansion section

Theoretical classification	**Teaching content**
Transformer	Vanilla Transformer principle and source code interpretation
	Variants: ViT, DeiT, Swin -Transformer Principles of Transformer
Self-supervised Learning	The principle and implementation of Auto-Encoder
	Masked AutoEncoder (MAE), SmCLR, MoCO, BYOL principle
Multimodal	Single tower structure: CLIP, ALIGN, SLIP Twin tower structure: VILT, UNITER

- Strengthen external relations and foreign communications. Through school-enterprise cooperation with artificial intelligence companies, to provide students with an internship platform, or to allow enterprises to participate in teaching, closely combining enterprise and social needs with personnel training, and truly integrating the knowledge learned with off-campus practice.
- Optimize the assessment method. The assessment should run through the whole process of teaching, from experimental assignments, project training results, group academic development discussions, academic paper study, final closed-book examinations, and other all-round and whole-process evaluations. The overall final evaluation grade after the reform is calculated as in (1).

$$\begin{aligned} \textit{final grade} = & \textit{Classroom Performance} \times 5\% \\ & + \textit{experimental score} \times 30\% \\ & + \textit{project Completion} \times 30\% \\ & + \text{academic paper study} \\ & \times \text{final examination} \end{aligned} \quad (1)$$

3.3 Implementation of Teaching Reform

As one of the most important courses for an artificial intelligence major, the teaching method should be systematic and coherent. For this reason, we carry out curriculum teaching reform in three stages. The reform model and roadmap is shown in Fig. 1.

The first stage: is the basic stage. The main feature of this stage is the integration of theoretical and practical teaching links, eliminating the separation of traditional computer courses theory courses, and computer courses. Leveraging the interactive courseware developed by Anaconda Jupyter allows teachers to program while teaching theories, and students can also practice by hands-on exercises simultaneously, diluting the traditional practice of conducting hands-on experiments only after taking computer classes. The basic theoretical knowledge of computer vision is enhanced through practice, and the experimental content is knowledge points of project teaching.

The second stage is the application stage. After the previous stage, this stage will focus on exercising the ability to comprehensively apply knowledge to integrate disciplines, so that students can enter the intensive training stage with each computer vision sub-module realized in the basic stage. We integrate classroom learning through comprehensive case scenarios. At this stage, students will complete the comprehensive design of multiple projects, combined with engineering practice, inspire students' multi-directional thinking, give full play to students' subjective initiative, and stimulate students' creative inspiration and enthusiasm for innovation.

The third stage: is the innovation stage. Based on the first two stages, students already have a certain understanding and practical ability to apply computer vision in

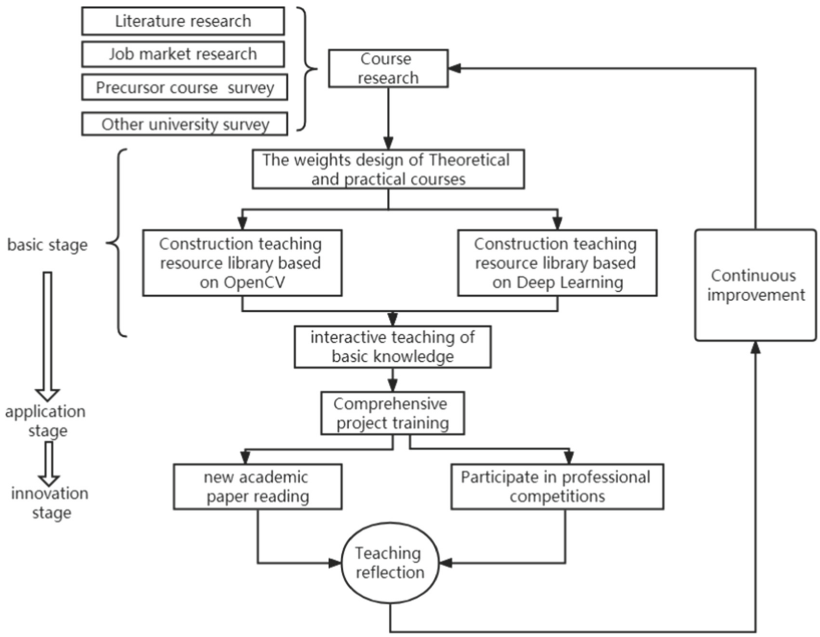

Fig. 1. "Four modes Three Stages" reform model

Table 5. Class Attendance

Class	No. of people	Before the reform/%	After the reform/%	Growth margin/%
2019	50	96	100	4
2020	47	98	99.5	1.5
2021	48	97.5	100	2.5

various branches of engineering or academic fields. At this stage, we should be "student-centered", and encourage or guide students to participate in artificial intelligence professional competitions such as Kaggle, Ali Tianchi, and Teddy Cup. We need to organize students to work independently from literature reading, program formulation, feasibility analysis, model design, code writing, model training, and optimization, summarizing and writing papers, etc. We give full play to the initiative of our students. Let students learn to analyze and solve the problems encountered in the actual design and debugging process, to cultivate innovative awareness, hands-on practical ability, and rigorous scientific research attitude, and continuously improve the ability of independent learning and unity and cooperation.

4 Results

We take our university as an example of carrying out the teaching reform of computer vision in three stages and have achieved good teaching results. The "Basic-Application-Innovation" phased reform proposed in this paper has been effective, the course assessment results have increased significantly, and the percentage of subject competition awards has increased compared to previous years.

4.1 Enhanced Students' Ability for Self-directed Learning

We randomly selected five average student attendance rates from three teaching courses before and after the reform for data analysis. Table 5 demonstrates that students' interest in learning has grown, and class attendance rates are rising after the reform. Based on student interviews, it has been concluded that, in general, students find this method of instruction and evaluation challenges. They can carefully complete the project content in small groups according to the requirements. According to Table 6, after four weeks of after-school learning research in three teaching courses, the average time students spent on self-study of the computer vision course through China University MOOC exceeded three hours per week. Students' engagement, interest in learning, and completion rate have significantly increased due to the project's classification, which led to a more logical organization of the experimental material and more affluent, clearer practical content.

4.2 Significant Improvement in Course Grades

Before the reform, the majority of the course grade was determined by the paper grade of the final exam, the attendance grade, and the homework grade. However, a paper-based assessment does not accurately reflect students' actual abilities. Therefore, we've

Table 6. Students' Self-learning after Class

Class	No. of people	Before the reform/(hours per week)	After the reform/(hours per week)	Growth rate/%
2019	50	2	3.5	75
2020	47	2.8	4	42.8
2021	48	3.1	4.3	38.7

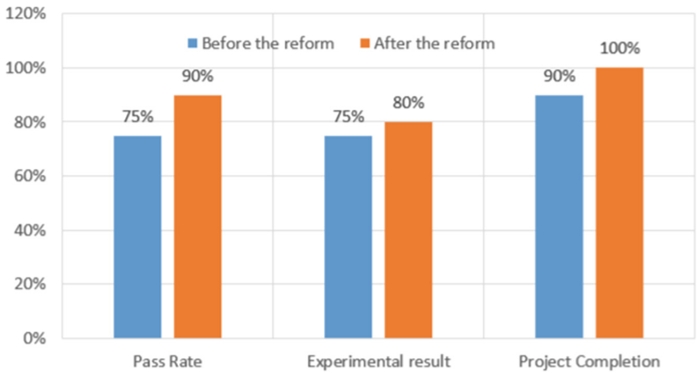

Fig. 2. Analysis of Study Performance

developed a comprehensive assessment method to evaluate the learning process. The evaluation of the entire process may foster a culture of continuous learning and teamwork for students while providing ample room for their creativity and initiative. The grade comprises regular assignments, experiment completion, project completion, academic growth, and the final test mark. The course pass rate has grown from 75% to over 90%. The number of students with an average laboratory grade of 80 increased by five percentage points compared to the number of references before the course reform, as shown in Fig. 2.

4.3 Number of Student Competition Awards Increased

In recent years, there have been more and more information competitions at all levels, such as the "Blue Bridge Cup" National Software and Information Technology Professionals Competition, the Information Technology Practice and Innovation Competition, the "Teddy Cup" Artificial Intelligence Challenge, and the Baidu AI Studio Platform Competition. In terms of student achievements, they have won more than ten professional competition awards from the provincial level and above in the past two years. They can easily get the TOP10 ranking in the Baidu AI Studio platform competition and the "Teddy Cup" artificial intelligence challenge.

After the practice of teaching reform, the experience and insights are summarized as follows:

- In order to extend the academic horizons of students and invigorate the classroom, interdisciplinary teaching projects must be carefully selected. They should have a particular technical-theoretical frontier but also be able to solve practical problems in cross-cutting areas and have good application value. The training results can support students participating in disciplinary competitions, writing academic papers, etc.
- Using disciplinary competitions and instructors' research projects as a fulcrum, we foster the subjective initiative of students and build their innovative, practical talents. The outcomes of academic competitions, creative projects, academic papers, and other helpful training results not only provide students with a genuine sense of accomplishment in developing and landing projects but also aid them in subsequent processes, such as applying for scholarships and taking graduate school entrance exams.
- The complete quantitative assessment of students fosters a culture of continual learning, teamwork, and initiative while providing ample room for creativity.

In general, through the optimization of teaching contents and innovation of teaching mode in the computer vision course, the concept of "student development as the center" is implemented in each teaching stage, which has increased students' comprehensive ability, fully stimulated students' interest and desire to explore in the computer vision course, and fostered students' creative ability to use artificial intelligence technology to analyze and solve practical problems.

5 Conclusions

This paper covers the reorganization of the "Computer Vision" course in light of the requirements of "Emerging Engineering Education" and the training of talent in artificial intelligence. The proposed "Four modes Three Stages" reform model is centered on the student's growth and examines techniques and ideas for optimizing teaching contents and resource allocation, innovating teaching modes and means, enhancing students' practical exercises, and fostering their academic research skills. During a project's design, implementation, and operation phases, students' engineering practice ability and collaborative spirit are enhanced, their excitement for learning continues to rise, and their research literacy is steadily strengthened. This paper's findings positively influence the improvement of computer vision course instruction. In the future, it will be necessary to strengthen further the integration of industry and education, school-enterprise cooperation, and updating teaching content to integrate talent training more closely with social needs. The instruction of courses should facilitate the development of inventive practitioners with a multidisciplinary background in artificial intelligence.

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